OPERATION AND MAINTENANCE INSTRUCTION MANUAL FOR IRD MECHANALYSIS VIBRATION-SOUND LEVEL METER MODEL 308

CHANGE B, PCO 1609, AND
CHANGE C, MISCELLANEOUS CORRECTIONS,
SERIAL NO. 300 AND ON

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CHANGE B, PCO 1609, AND CHANGE C, MISCELLANEOUS CORRECTIONS, SERIAL NO. 300 AND ON

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IRD Mechanalysis, Inc.
6150 Huntley Road
Columbus, Ohio 43229
614/885-5376
Fax: 614/885-7668
Telex: 245318

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Errata Sheet

Model 308 Operation Manual

For Model 308 Rev. "**C**" Versions :

1) P/N 05294 Microphone is now P/N 37674

2) P/N 12433 Pickup Cable is now P/N 37678

3) 3-Pin Pickup Connector P/N 21686 is now a 4-Pin Connector P/N 21685.

4) R31 was changed from an 80.6K resistor to a 499K resistor.

For Model 308 Rev. "**D**" Versions :

1) R31 was changed from an 499K resistor to a 332K resistor.

2) Pot P2 was changed from a 200K Pot to a 500K Pot.

IRD Mechanalysis, Inc. June, 1994

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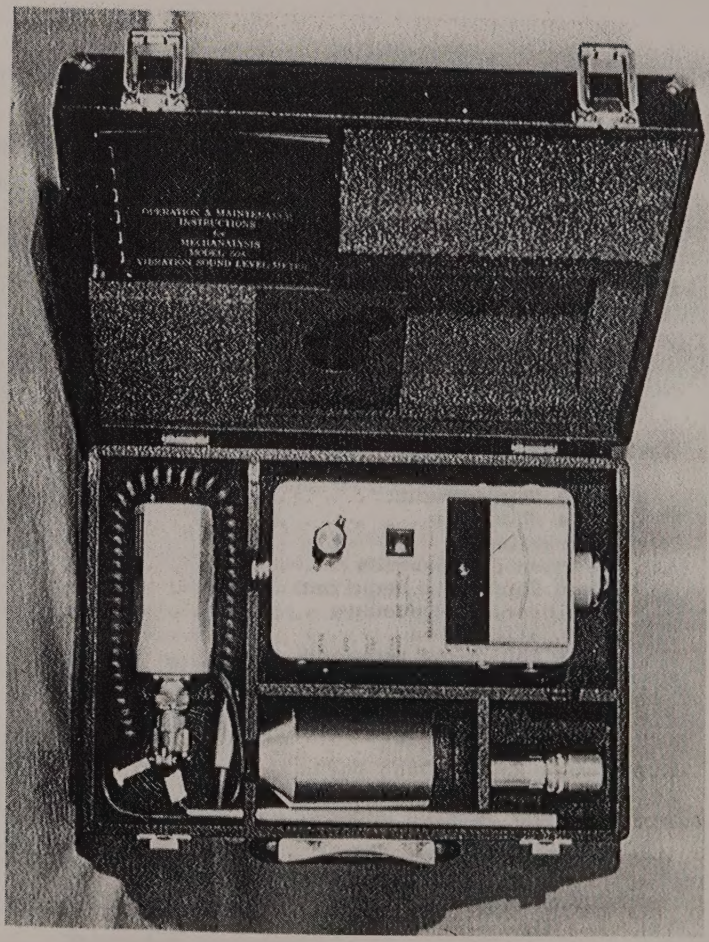


Figure 1. Model 308 Vibration/Sound Level Meter

INTRODUCTION

The Model 308 Vibration/Sound Level Meter, by combining in a single instrument the capability of measuring either vibration or sound, provides a unique three-fold approach to the control of machinery problems and noise pollution.

1. Conditions in a machine that can eventually result in breakdown can be detected by periodic vibration readings of the machine, using the Model 308. As periodic readings increase trouble is indicated. The cause of the trouble can then be analyzed and corrected, preferably with the use of a Vibration Analyzer/Dynamic Balancer instrument.

2. As a general rule, an increase in the vibration of a machine will also result in increased noise levels near the machine. Using the Model 308 for periodic noise measurements in the immediate area of specific machines can indicate developing trouble in the same manner as vibration readings. In many cases one type of measurement will confirm the trouble indicated by the other. Additionally, it is important to note that periodic noise measurements can uncover some types of machinery problems which might not be detected by vibration measurements.

3. The Model 308 provides the means for carrying out an effective program of noise pollution measurement and control. Such programs, whether elective or to achieve compliance with Local, State or Federal "Standards," imply the use of a sound level meter which will provide consistent accuracy as related to accepted measurement standards. To provide this accuracy, the Model 308 is designed

to meet or exceed the specifications of American National Standards Institute (ANSI) S1.4-1971 for Type 2 Sound Level Meters, and International Electrotechnical Commission (IEC) Recommendation 123 (1961) and British Standard BS3489: 1962.

This manual fully describes the Model 308 Vibration/Sound Level Meter and provides details on its operation, application and maintenance. It is recommended that the manual be read throughout before the instrument is used.

Combined with the knowledge represented in this manual, the Model 308 is an effective and valuable tool for dealing with many types of routine vibration and noise problems. However, problems beyond the "routine" require more sophisticated equipment and more knowledge. IRD Mechanalysis offers both. An extensive line of analysis equipment (including Real Time) is available, and is backed by complete and complimentary training courses in both vibration and sound, at basic and advanced levels. Basic courses are available in all Mechanalysis Districts, worldwide.

DESCRIPTION

GENERAL

The Model 308 Vibration/Sound Level Meter, figure 1, provides the capability of measuring either vibration or sound in one compact, easy to use instrument. The Model 308M Vibration/Sound Level Meter (not illustrated) is identical to Model 308 except that vibration amplitude is read in Metric units instead of English units. All information relative to Model 308 applies equally to Model 308M except where specifically stated otherwise. The portable, battery-powered meter is supplied with a rugged carrying case which also holds the instrument manual, microphone, vibration pickup, and pickup accessories provided. A carrying strap for the meter simplifies measurements and data recording. Figures 2 and 3 illustrate the Model 308 being used as a vibration meter and as a sound level meter.

The Model 308 is designed to meet the specifications of ANSI Standard S1.4-1971 and IEC Recommendation 123 (1961). Micro-power integrated circuitry in the meter ensures reliability, extended battery life, and linear accuracy over a wide frequency range.

Specific details of controls and components are given in the remaining paragraphs of this section. Meter features are illustrated in figure 4.

MEASUREMENT MODE PUSHBUTTONS

Two vibration measurement modes (black DISP and VEL pushbuttons) and three sound level measurement

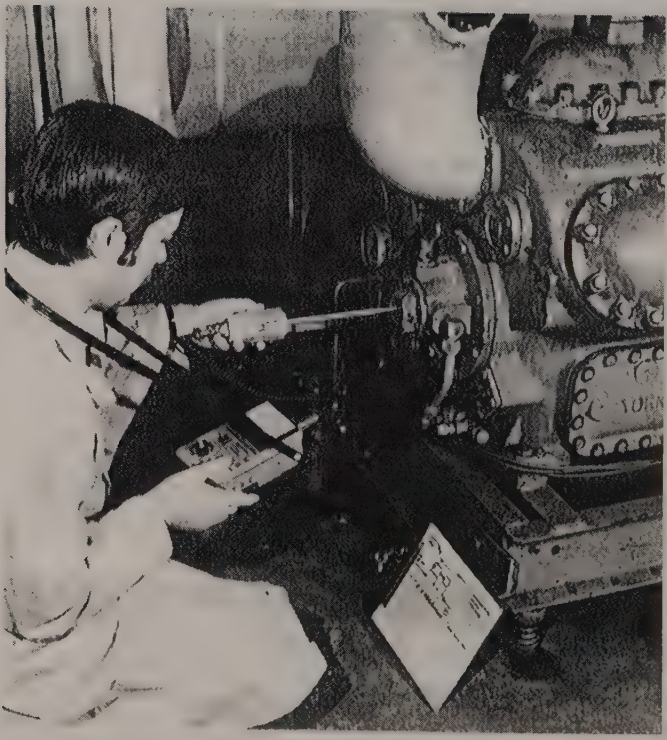


Figure 2. Model 308 Used as Vibration Meter

Figure 3. Model 308 Used as Sound Level Meter

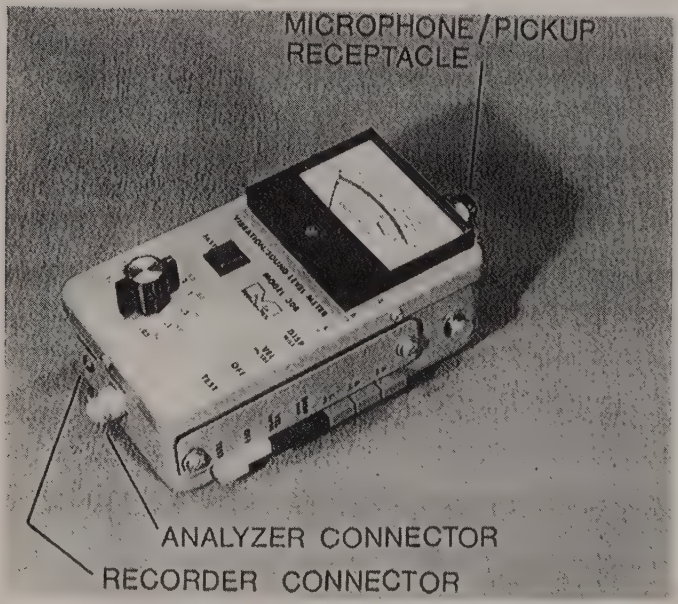


Figure 4. Instrument Features

modes (red A, B and C pushbuttons) may be selected. (The A, B and C modes select, respectively, the A, B and C frequency response "weighting" networks in the meter.) The five mode pushbuttons are "ganged" with the white OFF pushbutton; that is, depressing any one of the six pushbuttons will automatically return any previously depressed pushbutton to the "out" position. The gray TEST pushbutton operates independently; when depressed, battery condition is satisfactory if the amplitude meter reads within the TEST area on the meter face. (The TEST function does not work when the OFF pushbutton is depressed.)

FAST RESPONSE PUSHBUTTON

When the Model 308 is used to measure sound level, the meter circuitry is normally set up to obtain a relatively slow readout response to changes in the sound levels being measured. The AMPLITUDE METER indications are steadier, and the intermittent rapid changes in the sound level being measured are somewhat averaged in the instrument indications. However, if desired, the occurrence of the rapid level changes or the amount of the changes can be observed by depressing the red spring-return FAST pushbutton. This operation alters the meter circuitry to provide a faster response.

The AMPLITUDE METER should be interpreted in accordance with the settings of the AMPLITUDE RANGE and MODE selectors. The eight ranges with black numbers are used for measuring vibration, and provide a total span of from 0 to 100 mils (0 to 3000 micrometers, in metric), peak-to-peak, if the DISP (displacement) mode is used. If the VEL (velocity) mode is used, a total span of from 0 to 100 inches per second (0 to 3000 mm/sec, in metric), peak, is provided.

NOTE: 1 mil is equal to 0.001 inch, 1 micrometer is equial to 1×10^{-6} meter, and mm/sec means millimeters per second.

The nine ranges identified with red numbers are used for measuring sound level, and provide a total measuring span of from 45 to 140 decibels (dB's) (re 0.00 oz microbar) if either the A, B, or C weighting network is also selected. Instructions for interpreting the AMPLITUDE METER readings are

given in the Operation section.

MICROPHONE/PICKUP RECEPTACLE

The MICROPHONE/PICKUP receptacle accepts either the microphone or the vibration pickup cable connector. The receptacle is designed to positively lock the mating connector when fully seated; the release button on the receptacle must be depressed to remove the microphone or pickup cable connector.

ANALYZER AND RECORDER OUTPUT CONNECTORS

The ANALYZER and RECORDER output connectors are shown in figure 4. The ANALYZER output provides a means of frequency analysis of sound level measurements. The output is interconnected with the pickup input of a Mechanalysis Vibration Analyzer/Dynamic Balancer (Model 330, 340 or 350). The analyzer filter is then tuned to locate the specific frequencies contributing to the overall amplitude indicated on the Model 308. The amplitude of each frequency located can also be determined.

The RECORDER output provides a means of obtaining Amplitude vs Time recordings of vibration or sound levels monitored with the Model 308. The output is a d-c voltage which is proportional to the amplitude of the vibration or sound level being monitored, and is compatible with a variety of d-c recorders. A jack which mates with the RECORDER connector is provided as standard equipment with the meter. Recordings of vibration levels can be very useful for purposes such as studying the effects of various changes (load, temperature, etc.) or for more continuous monitor-

ing of a machine when the measurements are approaching critical levels. Sound-level recordings are similarly useful for machinery problems, and for purposes such as determining maximum area noise levels to which personnel are or may be exposed, and duration of exposure.

Additional details regarding the ANALYZER and RECORDER outputs are given in the Operation and Specifications sections.

BATTERIES AND COMPARTMENT

The battery compartment is located behind the access cover plate above the mode selector pushbuttons. Two 8.4-volt mercury batteries are supplied; polarized snap-on connectors permit foolproof battery installation. The access cover is secured with two captive screws.

VIBRATION PICKUP, PROBE AND CABLE

The Model 544 Vibration Pickup may be used with or without the 9-inch accessory probe provided. The pickup is interconnected with the meter MICROPHONE/PICKUP receptacle using the 4-foot nonretractile cable. The pickup produces an electrical output voltage proportional to the vibration velocity of the machine part to which it is applied. (Circuitry in the meter converts the velocity-related signal to a displacement-related signal, when the DISP mode is selected.) Complete characteristics are given in the Specifications section.

The pickup may be mounted using a 1/4-28 stud (welded or threaded to the machine part) to mate

with the hole in the pickup end cap. It may also be hand-held. Mounting position does not affect sensitivity or accuracy. For hand-held measurements, the end of the pickup may be applied directly to the point of interest, or the 9-inch probe may be installed; the probe permits better access to hard-to-reach points. Optional Vise Grip or Magnetic Holders permit quick, "hands-free" application of the pickup.

MICROPHONE

The microphone is omnidirectional (equally sensitive to sound arriving from all directions) and utilizes a ceramic sensing element. The microphone features a wide frequency response and is designed strictly for sound level measurements. (See Specifications section for additional details.) The microphone installs directly in the MICROPHONE/PICKUP receptacle, thus eliminating cable noise or cable impedance matching problems. (Use of an extender cable for connecting the microphone to the Model 308 is not recommended.)

CARRYING CASE

The carrying case is divided into compartments for the instrument, operation manual, and various accessories. Foam padding in the compartments provide additional protection for the meter and accessories. A projection in the meter compartment depresses the OFF pushbutton when the meter is placed in the compartment. Space is provided in the carrying case for two spare meter batteries, and for the optional Sound Level Calibrator (see "Optional Accessories").

SPECIFICATIONS

GENERAL INSTRUMENT SPECIFICATIONS

RECORDER Output:	D-C output proportional to amplitude meter reading. Compatible with strip chart recorders having 200 microampere d-c sensitivity, 5000 ohms resistance.
ANALYZER Output:	A-C output proportional to meter reading. Full-scale a-c output is 764 millivolts (301 millivolts, Model 308M) rms into an impedance of 100,000 ohms. (Compatible with Mechanalysis Model 330, 340 or 350 Vibration Analyzer/Dynamic Balancer instruments or conventional oscilloscopes.)
Battery requirements:	Two NEDA Type 1604 8.4-volt or 9-volt batteries. (Two 8.4-volt mercury batteries supplied.)
Suitable Battery Types and Average Life:	1. Mercury; approximately 500 hours. (Mallory Duracell TR 146X; Eveready E146X; Burgess 146X.) 2. Alkaline; approximately 300 hours. (Mallory MN1604; RCA 1323.) 3. Zinc-Carbon; approximately 150 hours. (Eveready 216; Burgess 2U6; RCA VS323; Mallory M1604.)
Battery Condition:	TEST pushbutton provides meter indication of battery condition.

Temperature Range:	0°F to 150°F. (-18°C to 65°C)
Overall Dimensions:	Instrument 9 x 4-5/8 x 3-1/4 inches (22.9 x 11.8 x 8.3 cm) Carrying Case 13-1/4 x 10-1/4 x 4-1/2 inches. (33.7 x 26.1 x 11.5cm)
Weight:	Instrument with batteries: 2 pounds (0.9 Kg) Instrument with carrying case and accessories: 8 pounds (3.6Kg) Shipping weight: 10 pounds (4.5Kg)

INSTRUMENT AS VIBRATION METER

Frequency Range:	720 to 60,000 CPM (12 to 1000 Hz), with Model 544 Vibration Pickup used as sensing transducer. (Instrument range is 300 to 600,000 CPM, or 5 to 10,000 Hz.)
Maximum Sensitivity:	Peak-to-Peak Displacement: 0.001 mils (0.03 microns, Model 308M).
	Peak Velocity: 0.001 inch per second (0.03 millimeter per second, Model 308M).
Amplitude Ranges:	Peak-to-Peak Displacement: 0 to 100 mils (0 to 3000 microns, Model 308M), in eight overlapping ranges.
	Peak Velocity: 0 to 100 inches per

second (0 to 3000 millimeters per second, Model 308M), in eight overlapping ranges.

INSTRUMENT AS SOUND LEVEL METER

Design Standards:	Meets or exceeds ANSI S1.4-1971 (Type 2) and IEC Recommendation 123 (1961) and British Standard BS3489: 1962
Frequency Response Weighting Networks:	A, B and C, per ANSI S1.4-1971.
Frequency Range:	20 to 10,000 Hz (1200 to 600,000 CPM), with Microphone Part No. 5294 used as sensing transducer. (Instrument range is 5 to 10,000 Hz, or 300 to 600,000 CPM.)
Amplitude Range:	45 to 140 dB (re 0.0002 microbar) in nine overlapping ranges, for A, B or C weighting networks.
Meter Response Rates:	"Slow" and "Fast" per ANSI S1.4-1971. Slow response except when FAST pushbutton is depressed.

MODEL 544 VIBRATION PICKUP SPECIFICATIONS

Type:	Seismic velocity; self-generating. The sensitive axis is the longitudinal axis, and is perpendicular to the mounting surface.

Output Sensitivity:	240 (± 24) millivolts ac (rms) output for a peak-to-peak displacement of 0.001 inch (1 mil) at 100 Hz (6000 CPM). This corresponds to a Velocity Constant of 1.08 volts ac (peak) output per inch per second of peak vibration velocity. Sensitivity is unaffected by orientation.
Orientation:	May be used in any mounting position without adjustment or correction.
Frequency Response:	Room ambient (± 77°F): ± 8% over the frequency range 12-1000 Hz; down 8% ± 13% @ 10 Hz; pickup frequency response drops exponentially at lower frequencies. Elevated ambient (+ 250°F): ± 13% over the frequency range 12-1000 Hz. The above limits are total variations for any mounting position of the pickup.
Transverse Response:	Average transverse response less than 5% of the longitudinal response, over the frequency range 10-1000 Hz.
Natural Resonant Frequency:	16 Hz critically damped at + 77°F.
Amplitude Range:	Minimum: limited only by amplifier gain and noise level. Maximum: 0.125 inch peak-to-peak displacement up to 70 Hz; 30 g's

	peak acceleration above 70 Hz.
Amplitude Linearity:	± 5% from 0.0001 to 0.1 inch peak-to-peak displacement.
Recommended Maximum Acceleration:	2.5 g's at 20 Hz to 30 g's above 70 Hz, continuous.
Damping Characteristic:	The pickup has a damping factor of approximately 0.7 which results in essentially flat operation over the frequency range. This provides improved accuracy and improved transient response for low frequency operation.
Magnetic Field Sensitivity:	Without shielding: 0.15 in/sec/gauss. With 10:1 Shield (Part No. 1157): 0.015 in/sec/gauss. With 100:1 Shield (Part No. 3563): 0.0015 in/sec/gauss.
Electrical Impedance:	2,000 (± 200) ohms DC resistance.
Temperature Range:	$-40^{\circ}F$ to $500^{\circ}F$.
Humidity:	Pickup case and connector are water-tight. Pickup performance is unaffected by humidity, condensation, and immersion in water for short periods.

Construction:	High-temperature solder connections. Machined aluminum case.
Mounting:	One 1/4-28 x 1/4" tapped hole for mounting to 1/4-28 stud in machine or in suitable bracket.
Weight & Dimensions:	21 ounces. 4-7/8" long x 2-3/16" diameter.
Output Connector:	ITT Cannon GS02-10SL-4P-111 High-Temperature, Hermetically Sealed (or equivalent).

MICROPHONE (PART NO. 5294) SPECIFICATIONS

Type:	Piezoelectric - ceramic; omni-directional.
Electrical Impedance:	460 pf capacitive (at 77°F).
Frequency Response:	20 to 10,000 Hz.
Sensitivity:	-60 (± 2) dB re 1 volt per microbar.
Distortion:	1% or less total harmonic distortion at 150 dB sound pressure level.
Temperature Range:	-50°F to +150°F.
Sound Pressure Extremes:	Cartridge will withstand momentary sound pressures in excess of 160 dB sound pressure level and 150 dB

Extremes: sound pressure level for at least 100 hours with no measurable change in characteristics.

Humidity: Cartridge will withstand 95 to 100% humidity for at least 1000 hours without deterioration.

STANDARD ACCESSORIES

1 - Model 544 Vibration Pickup, Part No. 4526
1 - Straight Probe, Part No. 1103
1 - 4 foot Pickup Cable, Part No. 12433
1 - Microphone, Part No. 5294
1 - Carrying Strap, Part No. 3829
1 - Operation Manual, Part No. 9765
1 - Plug, RECORDER Output, Part No. 9361
1 - Carrying Case, Part No. 9375

OPTIONAL ACCESSORIES

Spare Battery, 8.4-volt Mercury, Part No. 9291. (2 Required.)*

Sound Level Calibrator, Model 490, Part No. 10922. (Secondary standard which provides a known sound pressure level directly to the microphone, and insures consistant accuracy of sound level measurements.)

D-C Recorder, Strip Chart, Part No. 9405. For Vibration or Sound Level recordings, utilizing Model 308 RECORDER output. 117-volt, 60-Hz operation (234-volt, 50-Hz operation available.

* See "General Instrument Specifications" for suitable battery types available locally.

on request). Ten selectable chart-drive speeds: 3/4, 1-1/2, 3, 6 and 12 inches per hour, and 3/4, 1-1/2, 3, 6 and 12 inches per minute. (Maximum of 68 days continuous recording at 3/4 inch per hour.) Visual readout scales of 0 to 1 (linear) and -5 to +10 (dB, logarithmic) on recorder. Includes Accessory Kit (ink, pen filler, pen cleaner); one 103-foot roll of linear chart paper (0 to 1 scale); one 103-foot roll of logarithmic chart paper (-5 to +10 dB scale); one Recorder-to-Model 308 Interconnecting Cable, Part No. 9494; and one instruction manual. Additional details and specifications available on request.

Recorder Chart Paper, 103-foot roll, 0 to 1 linear scaling, Part No. 9406. (For 9405 Recorder.)

Recorder Chart Paper, 103-foot roll, -5 to +10 dB logarithmic scaling, Part No. 9469. (For 9405 Recorder.)

Magnetic Pickup Holder, Part No. 4332. (For use with Model 544 Vibration Pickup.)

Vise Grip Pickup Holder, Part No. 1821. (For use with Model 544 Vibration Pickup.)

Amplitude Meter Scale Overlay. (Provides dB scale on analyzer amplitude meter for performing sound analyses.)

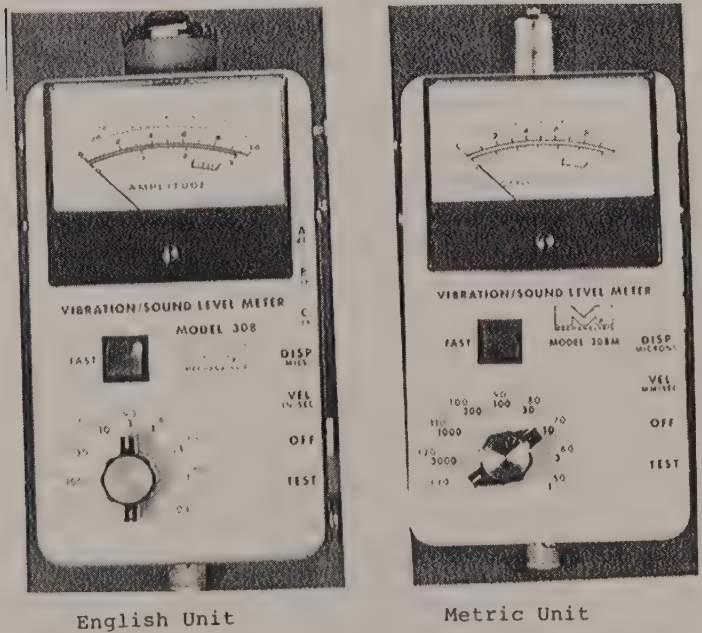
Model 330 - Overlay Part No. 5337
Model 340 - Overlay Part No. 5868
Model 350 - Overlay Part No. 9558
Model 600 - Overlay Part No. 9688

OPERATION

GENERAL

The scope of this section is limited to basic operating details. Actual instrument usage is described in practical terms in the following two sections, Vibration Measurement Techniques and Applications, and Sound Level Measurement Techniques and Applications.

Figure 5 illustrates controls and other meter details which will be discussed in this section.



English Unit

Metric Unit

Figure 5. Model 308 Panel Details

VIBRATION MEASUREMENT

The following steps are the basic requirements for preparing and using the meter for vibration measurements:

1. Confirm that the OFF pushbutton is depressed. Attach the carrying strap to the studs on the sides of the meter.

2. Connect the vibration pickup to the meter with the pickup cable. Press cable connector firmly into PICKUP receptacle to ensure that lock engages.

3. Select desired DISP or VEL measurement mode.

4. Depress the TEST pushbutton and confirm readout within the TEST area on the amplitude meter. If readout is below TEST area replace batteries as described in Maintenance section.

5. Apply the pickup to the point to be measured. (If pickup is to be threaded onto a mounting stud, disconnect cable at meter end.)

6. For each point to be measured set the range selector to successively lower (or higher) ranges until a meter reading within the upper two-thirds of the black scales is obtained. (This provides better meter accuracy than readings in the lower third of the scales.) The amplitude reading will be in mils (microns, Model 308M) of peak-to-peak displacement, or in inches per second (millimeters per second, Model 308M) of peak velocity, depending on whether the DISP or VEL mode is selected.

The black 0 to 1 scale is read if the range selected is ".1", "1", "10" or "100" ("1", "10", "100" or "1000", Model 308M), and the black 0 to 3 scale is read if the range selected is ".03", ".3", "3" or "30" ("3", "30", "300" or "3000", Model 308M). The meter full-scale value is equal to the range selected. For example, a reading of 2 on the 0 to 3 scale represents a value of 2 if the "3" range is selected, or a value of 20 if the "30" range is selected. Similarly, a reading of 0.6 on the 0 to 1 scale represents a value of 60 if the "100" range is selected.

7. Record the value of each measurement on a suitable data form, such as the one shown in figure 13 of the next section. (This form provides space for entering all pertinent information required, including sound level measurements.)

8. If the meter is to be used for an extended period of time, recheck the batteries once each hour and at the end of the use period. This practice will help to ensure consistently accurate readings.

SOUND LEVEL MEASUREMENT

The following steps are the basic requirements for preparing and using the meter for sound level measurements:

1. Confirm that OFF pushbutton is depressed. Attach the carrying strap to the studs on the sides of the meter.

2. Install the microphone in the MICROPHONE receptacle; press in firmly to ensure that lock

on the instrument becomes engaged.

3. Select the desired A, B, or C weighting network.

4. Depress the TEST pushbutton and check that the Amplitude Meter indicates within the TEST area of the meter scale. If the indication is below the TEST area, the batteries should be replaced (see details on Page 80).

NOTE: The Model 308 instrument should be checked for correct measurement of sound amplitude frequently. If feasible before using each day. The Sound Level Calibrator, Part No. 10922, is used with the Model 308 and the microphone for checking the sound level calibration. Details on checking the calibration are explained on Pages 84 and 85.

5. Set the Model 308 to the required measuring position, so that the microphone is pointed towards the primary noise source.

6. For each new measuring position selected, reset the AMPLITUDE RANGE selector so that the meter indicates within the 0 to +10 range on the dB scale (red scale). Indication within these values provides more accurate meter readings than between the -5 to 0 dB range. The value indicated on the dB scale should be added to the value to which the AMPLITUDE RANGE selector is set (the red number is used, i.e., 50, 60, 70, etc.). The sum of the two numbers equals the sound level in dB. (For example, if an AMPLITUDE RANGE setting of 70 were used, and a value of +5 dB were indicated on the red meter scale, the sound level value would be 75 dB. Or if an AMPLITUDE RANGE setting of 70 were used, and a value of -2 dB were indicated on the meter, the sound level value would be 68 dB. In the second example, an AMPLITUDE RANGE setting of 60 should have been used. This would have produced an indication of +8 dB, 68 dB level, but with a more accurate and reliable Amplitude Meter indication

and scale readability.)

7. Record each measurement on a suitable data form which has space to include all other information pertinent to the measurement. When recording measurements, the weighting network (A, B, C) used must be noted on the data sheet, or with the individual measurement values as indicated in the following examples: 79 dB(A); 85 dB(B), 92 dB(C), etc. If the measurements are being taken as part of a machinery preventive maintenance program, a dual-purpose form with space for both sound and vibration readings may be used (see figure 13 in the following section).

8. If the meter is to be used for an extended period of time recheck the batteries once each hour and at the end of the use period. This practice will help to ensure consistently accurate readings.

Using FAST Response Pushbutton

If the sound level being measured is not relatively constant, and has short-duration "peaks," a better approximation of the highest sound level will be obtained by depressing the FAST response pushbutton. This reduces the amount of electrical meter damping which is normally in the circuit to provide "slow" response. (Slow" and "Fast" response rates are as defined by ANSI.)

UTILIZING RECORDER OUTPUT

The RECORDER output is a d-c voltage which varies directly in proportion to the amplitude meter reading. The output may be used to obtain Ampli-

tude vs Time recordings of either vibration or sound levels. The Mechanalysis D-C Recorder (Part No. 9405) is ideally suited for this purpose. Other d-c recorders with a full-scale sensitivity of up to 200 microamperes with input resistance of 5000 ohms may also be used, with proper impedance matching. The RECORDER jack mating plug provided and a suitable two-conductor cable are used to interconnect the meter and recorder. The amplitude meter of the Model 308 is automatically switched out of the circuit when the mating plug is inserted in the RECORDER jack; positive d-c output voltage is applied to the tip (or center conductor) of the plug.

The full-scale d-c output (for any amplitude range) is one volt at 200 microamperes into a d-c impedance of 5000 ohms. D-C Recorder Part No. 9405 is furnished with Cable Part No. 9403. It requires no special matching and may be connected directly to the meter. Impedance matching requirements for other recorders should be such as to draw 200 microamperes into 5000 ohms at full-scale meter signal.

NOTE

Impedance matching errors will result in recorded amplitude errors.

If the recorder to be used has a variable sensitivity control, it may be calibrated by (1) applying a constant vibration to the pickup or a constant sound pressure level to the microphone, (2) observing the resulting meter reading, and (3) connecting the recorder and adjusting the amplitude for the previously observed meter value.

NOTE

- When making sound level recordings to determine maximum personnel exposure levels occurring over a given time period, use of 90 dB or higher ranges is recommended since recorded levels which exceed 90 dB(A) are of primary interest.

- For vibration recordings, use the amplitude range which will include the maximum vibration amplitude anticipated.

UTILIZING ANALYZER OUTPUT

The ANALYZER output is primarily intended to permit frequency analysis of sound level measurements, using a Mechanalysis Model 330, 340 or 350 Vibration Analyzer/Dynamic Balancer. The output may also be used for oscilloscope observation, when using either vibration or sound level measurement modes. (A suitable mating connector for scope interconnection is IRD Mechanalysis Part No. 4366 or ITT Cannon MS3106E-10SL-4S, or the equivalent.) The output signal is an a-c voltage proportional to the meter reading. The full-scale a-c output (for any amplitude range) is 764 millivolts (301 millivolts, Model 308M) rms into an impedance of 100K ohms.

Use of the ANALYZER output for frequency analysis of vibration measurements would be redundant; that is, if vibration frequency analysis (or balancing with phase readout) is desired, simply connect the vibration pickup directly to the Analyzer/Balancer instrument.

For frequency analysis of sound level measurements proceed as follows:

1. The C network on the Model 308 should be selected for all analysis work. (The purpose of analysis is to detect all frequencies contributing to the noise. This purpose will be defeated if the A or B network is selected, since lower frequencies may be attenuated to the point where they cannot be detected.)

2. Connect Analyzer pickup cable to Model 308 ANALYZER connector and to Analyzer PICKUP connector.

3. On the analyzer, set the DISP/VEL selector to "VEL" and the amplitude range selector to 1. (On metric units, set amplitude selector to 10.)

4. Adjust the Model 308 range selector for a meter reading on the dB scale.

5. Apply power to the analyzer and analyze the input signal in the same manner as for vibration frequency analysis. (Refer to analyzer operation manual for details.)

6. The amplitude of the frequency component that is "tuned in" is equal to the sum of the dB range switch setting on the Model 308 plus the dB meter reading on the analyzer.

If this amplitude is too small to read on the analyzer meter, the analyzer amplitude range switch should be switched to a lower scale. Each step is equivalent to subtracting 10 dB from the dB shown on the Model 308 range switch. (Do not reduce analyzer switch more than 2 steps, that is, 20 dB. Filter overloading may occur and erroneous readings obtained.) The dB sound pressure level of the "tuned in" frequency is equal to the sum of the Model 308 dB setting minus 10 dB for each analyzer step change plus dB reading on the analyzer meter.

For example, if the Model 308 is set to 60 dB, and the analyzer to .3 (for metric units, the analyzer range switch would be set at 3), and the analyzer meter reads +9 dB, the sound pressure level of the "tuned in" frequency is 60 dB - 10 dB + 9 dB or 59 dB. See Figure 5A.

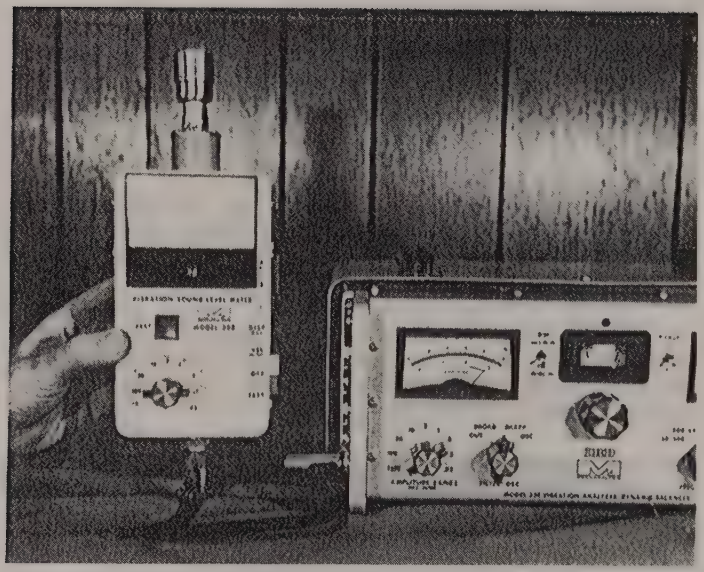


Figure 5A. The filtered sound pressure level component reading is +59 dB. It is the sum of the Model 308 and 350 amplitude range selector settings and the Model 350 amplitude meter readings +60 dB, -10 dB and +9 dB respectively.

APPLYING THE PICKUP

Meaningful and accurate machinery vibration readings require reasonable care in selecting the points (on the machine) to be measured, and proper application of the pickup to those points.

The most significant measurement points will usually be at the bearings which support the major rotating component(s), or on solid machine structure as near the bearings as possible. These points are the best "transmitters" of the machine's vibration.

At a given measurement point (or bearing) on the machine, three "standard" measurement positions of the pickup may be used. These positions - "Axial," "Vertical" and "Horizontal" - are illustrated in figure 6. (For data-recording purposes the positions are abbreviated "A," "V" and "H.") The three measurements, when compared with each other and/or with their previous values, can provide important clues as to type or magnitude of possible problems.

Methods for applying the pickup are listed below. Factors which may affect the accuracy (or desirability) of these methods are given immediately after the list, and should be studied carefully.

1. Hand held, with pickup end cap directly against vibrating part.

2. Hand held, with pickup probe against vibrating part, as shown in figure 6.

3. Attached to machine with vise grip holder or magnetic holder (optional pickup accessories) as shown in figure 7.

4. Installed on 1/4-28 stud welded on or threaded to machine part. See figure 7. (Mounting surface must be flat and stud square with surface to ensure good readings.)

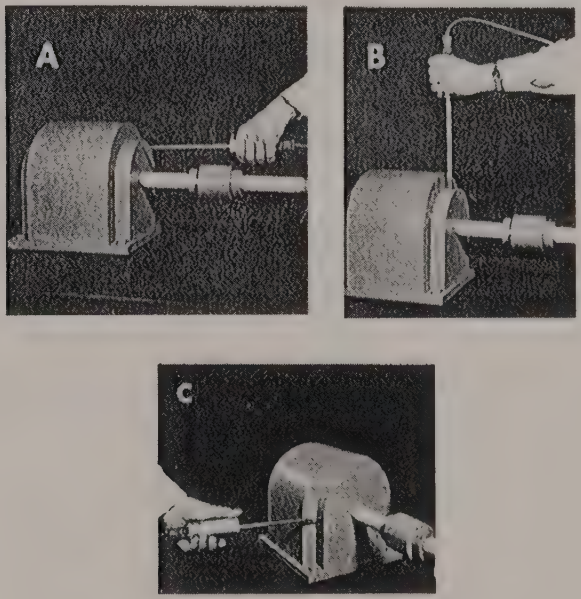


Figure 6. "Standard" Pickup Positioning

Vise Grip Holder

Magnetic Holder

Mounted on Stud

Figure 7. Applying Pickup for "Hands—free" Measurements

When hand-holding the pickup (with or without probe installed) use just enough force to prevent any chattering between the part and the pickup (or probe) - don't "lean" against the pickup. Keep the pickup as steady as possible while taking the meter reading.

Repeat measurements of a given point are taken to show any change in machine condition, by comparing the measurement values. When taking repeat measurements it is important to use the same relative pickup position each time, since a change in relative position can cause a change in the comparative measurements. To ensure "repeatability" when using methods 1, 2 or 3, make a practice of always placing the pickup in a reasonably true horizontal or vertical plane when conditions permit. If machine structure forces you to use an "unusual" pickup position, be sure to repeat that position for later measurements at the same point.

Methods 1 and 4 (hand held without probe, or stud mounted) may be used on machines or major machine components which operate at speeds of 720 to 60,000 RPM. The following methods are recommended only within the speed limits shown (due to "resonance" limits of the pickup accessories).

APPLICATION METHOD	SPEED LIMITS
Attached with vise grip holder	720 to 8,700 RPM
Hand held, with 9" probe	720 to 16,000 RPM
Attached with magnetic holder	720 to 37,000 RPM

MEASURING DISPLACEMENT

Vibration can be measured in terms of how far the part moves back and forth. This is called the peak-to-peak displacement or simply the displacement. The Model 308 measures this displacement in mils (or microns, Model 308M).

(1 mil = 0.001 inch; 1 micron = 1×10^{-6} meter.)

MEASURING VELOCITY

The Model 308 can also measure the vibration in terms of how fast the part moves. This is called the peak velocity and is measured in inches per second (or millimeters per second, Model 308M). Because velocity is a function of both displacement and frequency, it provides an added sensitivity to high frequency vibrations.

For instance, a vibration displacement of 0.1 mil (2.54 microns) results in the same meter reading when the frequency is 1800 CPM as it does at 18,000 CPM. The velocity for 0.1 mil at 1800 CPM is 0.0094 in/sec (0.239 mm/sec) but at 18,000 CPM the velocity is ten times as large or 0.094 in/sec (2.39 mm/sec). This means that small vibrations occurring at high frequency are easier to detect if velocity measurements are used. Since troubles such as bad bearings and gears cause vibration at high frequency, velocity measurements are extremely valuable.

VIBRATION TOLERANCES

Vibration measurements without a standard for comparison are seldom of any use. There must be some guide for determining how much is too much. Figure 8 provides a guide for Machine Tool vibrations.

TYPE OF MACHINE	Displacement of vibrations as read with pickup on spindle bearing housing in the direction of cut. Tolerance Range *
Grinders	
Thread Grinder	.01 – .04 mils
Profile or Contour Grinder	.02 – .08 mils
Cylindrical Grinder	.02 – .10 mils
Surface Grinder (vertical reading)	.03 – .2 mils
Gardner or Body Type	.05 – .2 mils
Centerless	.04 – .1 mil
Boring Machine	.04 – .1 mil
Lathe	.2 – 1.0 mils

* 1 mil = 25.4 microns

Figure 8 Guide to Machine Tool Tolerances

If machine tools vibrate beyond certain limits, the size or finish of the parts being machined will be unsatisfactory. The values listed indicate the range in which satisfactory parts have been produced. Actual tolerances must be determined by your own experience as to what vibration levels permit meeting size and finish tolerances.

For general types of machinery, the chart shown in figure 9 (or figure 10 if using Model 308M) may be used as a relative guide to how severe the vibration is. Of course, machine condition is considered to be progressively worse as severity increases from "Extremely Smooth" to "Very Rough." To interpret the severity when the machine vibration is measured in terms of displacement, the dominant (or principal) frequency of the vibration must be known. However, if the measurement is taken in terms of velocity, the severity can be read directly from the chart without knowing the dominant frequency. For example, a velocity reading of 0.1 in/sec (2.54 mm/sec) would indicate the severity (or condition) to be "Fair," regardless of the dominant frequency.

DETERMINING DOMINANT FREQUENCY

The Model 308 reads "overall" vibration. That is, if several vibrations (i.e., one at 1000 CPM, another at 2000 CPM, etc.) are present at the point being measured the meter reads the vector sum of all the vibrations. Usually one of these will be stronger (i.e., have more amplitude). This is the dominant vibration; knowing its frequency (or CPM) can tell us different things about the machine.

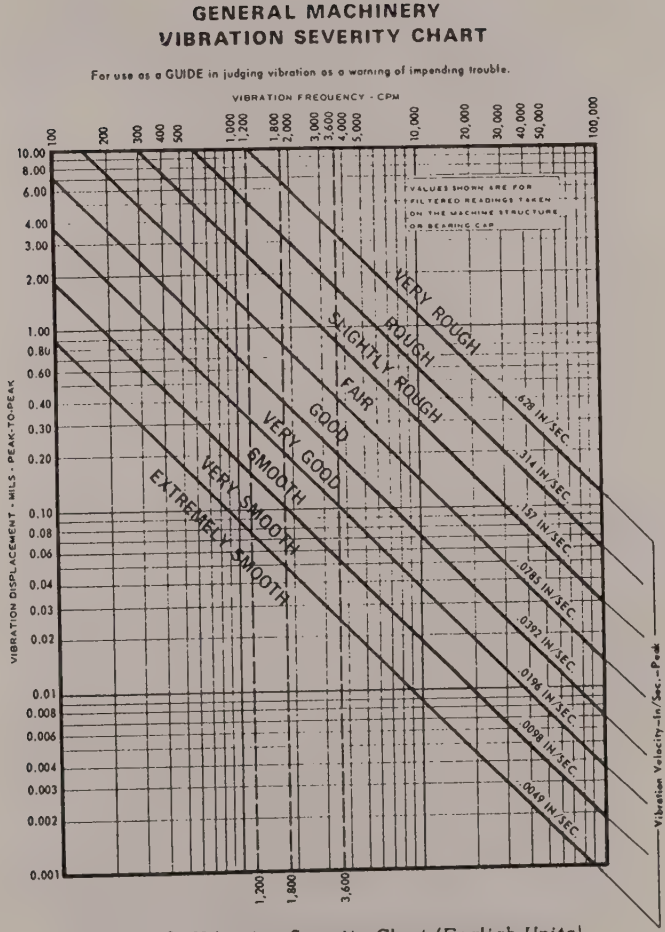


Figure 9. Vibration Severity Chart (English Units)

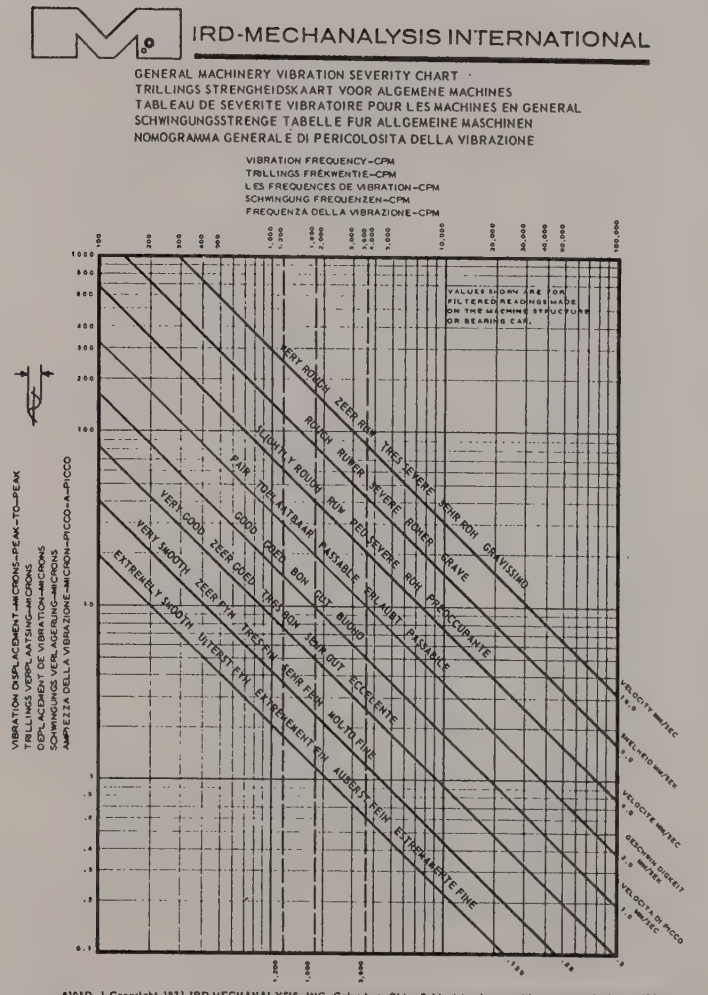

IRD-MECHANALYSIS INTERNATIONAL
GENERAL MACHINERY VIBRATION SEVERITY CHART
TRILLINGS STRENGHEIDSKAART VOOR ALGEMENE MACHINES
TABLEAU DE SEVERITE VIBRATOIRE POUR LES MACHINES EN GENERAL
SCHWINGUNGSSTRENGE TABELLE FUR ALLGEMEINE MASCHINEN
NOMOGRAMMA GENERALE DI PERICOLOSITA DELLA VIBRAZIONE
VIBRATION FREQUENCY-CPM
TRILLINGS FREKWENTIE-CPM
LES FREQUENCES DE VIBRATION-CPM
SCHWINGUNG FREQUENZEN-CPM
FREQUENZA DELLA VIBRAZIONE-CPM
VALUES SHOWN ARE FOR FILTERED READINGS MADE ON THE MACHINE STRUCTURE OR BEARING CAP.
VERY ROUGH ZEER RUW TRES SEVERE SEHR ROH GRAVISSIMO
ROUGH RUWER SEVERE RUDER GRAVE
SLIGHTLY ROUGH RUW REU SEVERE ROH PREOCCUPANTE
FAIR TOELAATBAAR PASSABLE TRILAUBT PASSABLE
GOOD GOED BON GUT BUONO
VERY GOOD ZEER GOED TRES BON SEHR GUT ECCELENTE
VERY SMOOTH ZEER FIJN TRES FIN SEHR FEIN MOLTO FINE
EXTREMELY SMOOTH UITERST FIJN EXTREMEMENT FIN AUSERST FEIN ESTREMAMENTE FINE
VIBRATION DISPLACEMENT-MICRONS-PEAK-TO-PEAK
TRILLINGS VERPLAATSING-MICRONS
DEPLACEMENT DE VIBRATION-MICRONS
SCHWINGUNGS VERLAGERUNG-MICRONS
AMPIEZZA DELLA VIBRAZIONE-MICRON-PICCO-A-PICCO
VELOCITY MM/SEC
SNELHEID MM/SEC
VELOCITE MM/SEC
GESCHWINDIGKEIT MM/SEC
VELOCITA DI PICCO MM/SEC
#305D-1 Copyright 1971 IRD MECHANALYSIS, INC. Columbus, Ohio. Subject to change without notice. Litho in USA.

Figure 10 Vibration Severity Chart (Metric Units)

The dominant frequency can be determined by taking both a velocity reading and a displacement reading at the same point with the Model 308 and then using the formula or chart solution described below.

CAUTION

- Although this method is in many cases a useful technique, use of a Vibration Analyzer is the preferred method for determining the specific vibration frequencies present.

- The dominant frequency cannot be accurately determined unless (1) both the VEL and DISP readings taken are very steady (i.e., the meter pointer does not change more than ± 5% from the average value observed) and (2) the relative position of the pickup is not changed when taking the two readings.

Figure 11 is the chart solution, and can only be used if displacement and velocity are both in English units, or are both converted to English units.

The formula solution is:

$$\text{DOMINANT FREQUENCY (CPM)} = \frac{V}{D} \times 19{,}120$$

where V is velocity in in/sec (mm/sec) and D is displacement in mils (microns).

(The chart in figure 11 can only be used if dis-

placement and velocity are in English units, and the actual dominant frequency is between 500 and 10,000 CPM.)

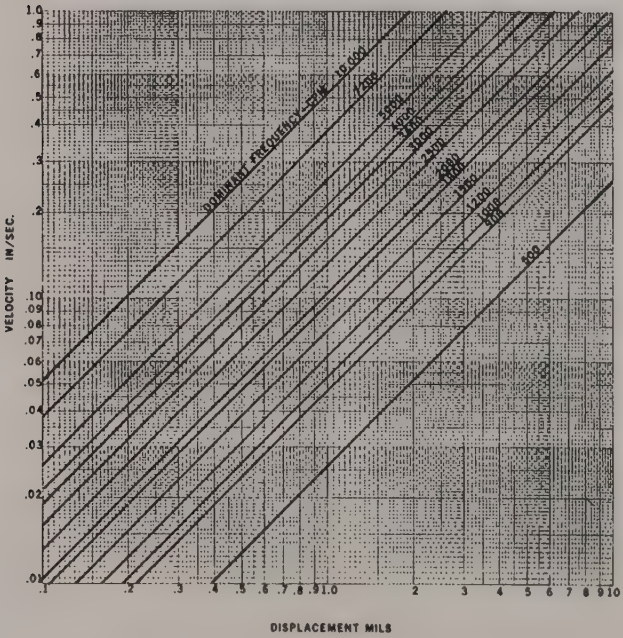
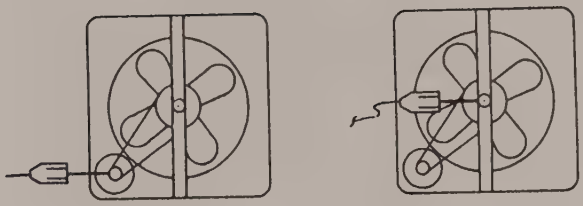


Figure 11. Chart for Determining Dominant Frequency

Significance of Dominant Frequency

Consider the belt-driven fan in figure 12. The motor and fan run at different speeds. The domi-



Measurements taken on motor contains vibrations of motor plus transmitted vibrations from the fan.

Measurements taken on fan contain vibrations of fan plus transmitted vibrations from the motor.

Figure 12. Transmission of Vibration

nant frequency will reveal which part of the machine is causing the most vibration. Measurements taken on the motor bearings would include vibrations of the motor plus vibrations from the fan transmitted through the drive belt and mounting structure. Conversely, measurements taken on the fan bearings would include vibrations of the fan plus vibrations transmitted from the motor. In many cases the point with the most vibration would pinpoint which part has the trouble, but not always. For example, structural design might cause the motor to vibrate more than the fan, even though the fan is the major cause of the vibration. To make a positive determination, the motor vibration is measured and found to have a displacement of D = 1.85 mils and a velocity of V = 0.255 inches per second. The dominant frequency is then calculated as:

$$\frac{0.255}{1.85} \times 19{,}120 = 2{,}649 \text{ CPM}$$

The motor and fan speeds are known to be 1,750 RPM and 2,600 RPM, respectively. From the calculation it can be concluded that the fan is the primary cause of the "overall" vibration measured at the motor. It can also be concluded that the cause of the fan vibration is probably unbalance, since unbalance of a rotating part causes a vibration frequency equal to its rotating speed. (It cannot, however, be concluded that only the fan is causing the vibration. After the fan is balanced, further measurements can indicate whether there is any significant trouble in the motor.)

Generally the dominant frequency will be equal to the rotating speed of the part causing the vibration, assuming that the trouble is unbalance. In any event the dominant vibration frequency will normally be some whole multiple of RPM of the part. After determining the dominant frequency, the type of trouble present may be assumed from the following:

DOMINANT FREQUENCY	MOST LIKELY TROUBLES
1 x RPM	Unbalance and/or misalignment. If axial measurement value is 1/2 the value of the horizontal or vertical measurement, or larger, check for bent shaft or misalignment of couplings or bearings.
2 x RPM	Loose mounting or misalignment.

	Use axial measurement to isolate, as stated above.
Many Times RPM	Bad gears or bad roller or ball bearings.

There are many other causes of vibration not listed. To pinpoint all but the simplest requires a thorough analysis of the vibration using a Mechanalysis Vibration Analyzer.

VIBRATION MEASUREMENT APPLICATIONS

Preventive Maintenance

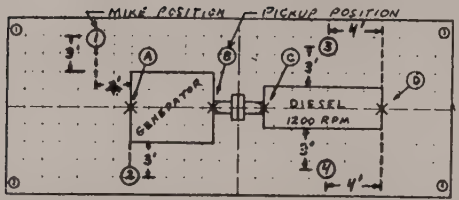
One of the most important applications of the Model 308 is making periodic vibration checks for preventive maintenance purposes.

The major phases of preventive maintenance are DETECTION, ANALYSIS, and CORRECTION. A measurable increase in the vibration of a machine is a symptom of wear or mechanical trouble. Periodic vibration measurements, recorded on a suitable data sheet such as shown in figure 13, provide the early DETECTION needed. Due to battery operation, size and simplicity of operation, the Model 308 is ideally suited for the DETECTION phase. The ANALYSIS phase pinpoints the cause of the trouble. Accurate vibration analysis requires the use of a Mechanalysis Vibration Analyzer/Dynamic Balancer. Once the problem is analyzed, CORRECTION can be scheduled for a convenient time; if unbalance is the problem, precise balancing can be achieved with the Analyzer/Balancer.

A primary requirement in setting up a preventive maintenance program is to initially establish the mechanical condition of each machine in the program. Although thorough measurements with the Model 308 can be of value, a true vibration analysis is best accomplished with an Analyzer/Balancer.

Note that the data sheet shown in figure 13 also includes provisions for recording periodic noise measurements. Noise measurements taken with the Model 308 can play an equally important role in

MECHANALYSIS PMP DATA SHEET



MACHINE: #2 SSDG
Component: DIESEL GENERATOR
Location: ENGINE ROOM

VIBRATION TOLERANCES ☐ DISP. ☒ VEL.		NOISE TOLERANCES dB(A) QUADRANT-	
A 0.157	D 0.314	① 90 dBA	
B 0.157	E —	② 90 "	
C 0.314	F —	③ 90 "	
		④ 90 "	

CHECKED DATE	BY	HOUSE-KEEPING	BELT CONDITION	LUBRICATION	NOISE LEVELS ①	②	③	④	VIBRATION LEVELS-IDISP. OR VEL.I A	B	C	D	E	F	REMARKS
5-17	JLP	OK	—	—	87	85	88	88	.03	.03	.15	.18			
6-21	JLP	✓	—	—	86	87	88	89	.04	.03	.20	.20			
8-4	JLP	✓	—	—	85	85	88	88	.03	.03	.21	.21			
9-12	JLP	✓	—	—	88	86	89	89	.03	.02	.24	.21			

Figure 13 Typical Vibration Data Sheet

preventive maintenance; additional details are given in the next section.

Balancing

In-place balancing is a routine procedure accomplished quickly and accurately with any Mechanalysis Vibration Analyzer/Dynamic Balancer. With its tunable filter rejecting all other vibrations, only the one from unbalance is shown on the amplitude meter; simultaneously the strob light fires on the component part to visually pinpoint the location of unbalance.

When a Mechanalysis Vibration Analyzer is not available or it's impossible to use a strob light, the Model 308 can be used for single-plane balancing under the following conditions:

UNBALANCE MUST BE THE MAIN CAUSE OF VIBRATION. Check to see if other causes of vibration such as misalignment of couplings or bearings, bent shaft, bad antifriction bearings, bad gears, mechanical looseness, etc. are present.

VIBRATION MEASUREMENTS MUST BE STEADY. The meter pointer must not fluctuate or slowly drift up or down scale more than about 10% of full scale.

THE DOMINANT FREQUENCY OF VIBRATION MUST BE THE SAME AS THE RPM OF THE PART BEING BALANCED.

If all three of the above conditions can be satisfied, use the following procedure for single-plane balancing.*

1. With the pickup, survey the part to be balanced for a point of maximum amplitude.

2. Attach the pickup at the point of maximum amplitude, using one of the methods shown in figure 7 if possible. (If the pickup is hand held make sure it is applied at the same point and in the same direction for all readings.)

3. Measure and record the original unbalance vibration. Call this reading 0.

4. Choose a trial weight. Carefully weigh and record the trial weight (TW).

5. Add the trial weight at any location on the part to be balanced and run the machine. Measure and record the vibration. Call this reading T_1.

6. Move the trial weight to a location exactly 180° from the first spot and at the same radius. Run the machine. Measure and record the vibration. Call this reading T_2.

* The procedure may also be used for two-plane balancing if necessary. Determine the plane (or rotor end) having the maximum vibration level and follow all steps to balance. Repeat the procedure for the second plane (other rotor end). Due to "cross effect" between planes, it may be found necessary to re-balance the first plane to achieve a good final balance.

7. With the above data, the amount of weight and the angular position necessary to balance the part may be determined. A sheet of paper, a ruler, protractor and compass are required.

8. Draw a circle with a radius equal to the original unbalance (0). The radius represents the original unbalance vector in MILS. A scale of one-half inch equals one mil is suggested. Then, draw a line vertically through the center of the circle that intersects the circle. The intersection at the top is point A, at the bottom, point B. See figure 14 Step A.

9. Using the same scale, draw an arc with a radius equal to the vibration reading T_1. The center of the arc is at point A. See figure 14 Step B.

10. Using the same scale, draw an arc with a radius equal to the vibration reading T_2. The center of the arc is at point B. See figure 14 Step C. Note that arcs T_1 and T_2 intersect in two places.

11. Draw a line from the center of the circle to one of the intersections of the two arcs. Using the same scale measure the length of this line in mils. Call this value R. See figure 14 Step D.

12. To determine the correct weight to balance the part, multiply original unbalance (0) in MILS by trial weight (TW) and divide by the resultant (R) in MILS.

$$\text{Balance Weight} = \frac{0 \times TW}{R}$$

13. To determine the angular location for the balance weight, measure with a protractor the angle between line A-B and line R. Call this angle M. See figure 14 Step E.

NOTE

The actual spot to attach the balance weight is either clockwise or counterclockwise by an angle equal to the measured angle M, from the spot where the trial weight was added for reading T_1.

14. Place the balance weight calculated in step 12 on the part at the measured angle M clockwise from the spot where the trial weight was first added to obtain reading T. If the vibration reading is not acceptable move the weight to a spot M degrees counterclockwise from the spot where the trial weight was added to obtain T_1.

Incoming Inspection

Vibration tolerances are often included in specifications of purchased components to prevent excess vibration in finished products. The Model 308 is ideal for inspection in receiving or on the assembly line.

Field Service

Field engineers and service men can quickly determine if vibration is the justifiable cause of a customer complaint. The portable Model 308 is easily carried to the job.

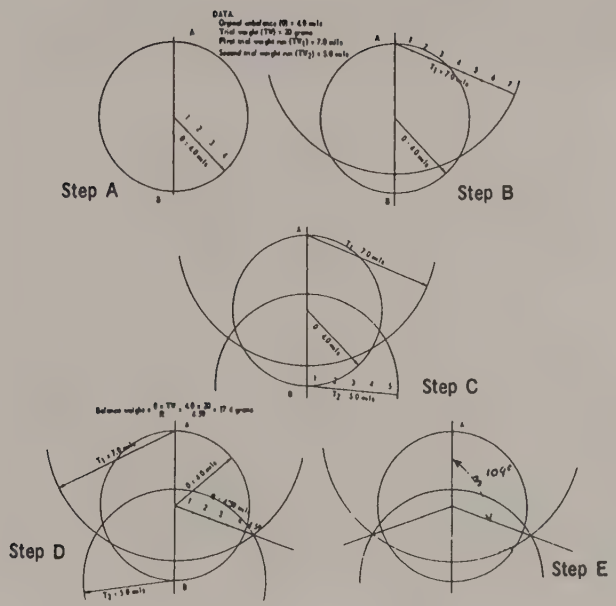


Figure 14. Step—by—step Balancing, Vector Diagram Construction

Final Assembly Testing; Installation Checkout

Final vibration checks of finished products and assemblies before shipment assures compliance with production quality standards and thus improves

customer satisfaction. New or overhauled machines can be checked for vibration from troubles due to faulty installation.

SOUND LEVEL MEASUREMENT TECHNIQUES AND APPLICATIONS

SOME FUNDAMENTALS OF SOUND AND NOISE

Basic Characteristics of Sound

Defined in technical terms, sound is a pressure oscillation in a fluid (water, air, etc.), which moves radially away from the source which produces it. Sound radiates by, or is "propagated" by, wave motion through the fluid or "medium." The four characteristics of this wave motion are amplitude, frequency, velocity and wavelength.

The velocity of sound is essentially "fixed" by the medium in which it travels; e.g., in air, 1100 feet per second; in water, 4800 feet per second. (Velocity changes somewhat with temperature or pressure changes of the medium.) The wavelength (λ) is the distance between similar points on two adjacent "waves," and is determined both by the velocity (c) and the frequency (F) at which the waves are propagated, or:

$$\lambda \text{ (feet/cycle)} = \frac{c}{F} \quad \frac{\text{(feet/sec)}}{\text{(cycles/sec)}}$$

The frequency of sound is determined by the source causing it. One of the most common sources of sound is a vibrating solid (see figure 15). The vibrating or oscillating motion of the solid causes pressure changes (or oscillations) in the surrounding air, and hence the pressure oscillation (or sound) frequency is the same as the vibration frequency of the solid. If a number of individual

components of the machine shown in figure 15 are each vibrating at a different frequency, the "overall" sound radiating from the machine will contain an equal number of individual "pressure oscillation" (or sound) frequencies.

The amplitude of sound is determined by how much the medium is alternately compressed and rarefied during the pressure oscillations caused by the source. Stated in another way, the amplitude is a measure of the energy imparted to the medium by the source. The initial energy imparted to the medium dissipates with distance; hence, at any given point away from the source the amplitude is also a measure of the energy which can be imparted by the medium to a "receiver" (such as a microphone, or our ear).

Sound amplitude is measured with an instrument (or sensed by our ear) in terms of the pressure level changes (relative to the average or "atmospheric" pressure of the medium) that take place during the pressure oscillations. Hence, "sound amplitude" is more commonly called "Sound Pressure Level" (abbreviated SPL).

In addition to "sound pressure level," the term "sound level" is also commonly used in place of "sound amplitude." If sound is measured with an instrument that is fully responsive to all frequencies of sound, then the measured value will be in terms of "sound pressure level" - that is, it will measure what is actually "out there," or the true sound pressure level. For reasons explained later (see "How the Ear Hears") it is also desirable to measure sound with instruments designed to be fully responsive to some frequencies but less

responsive to others. Such instruments are usually called Sound Level Meters, and readings obtained with them are (or should be) called "sound level" readings; that is, they are not meant to measure in terms of actual "sound pressure level."

What is Noise?

The generally accepted definition of noise is simply "unwanted sound." This includes everything from the drip of a faucet in the middle of the night to the mighty roar of a moon rocket as it leaves the launch pad. It can even include music, if it interrupts the work of the listener. To be considered "noise," all that is required is that it be sound that is undesirable to the listener. In fact, in all of the preceding (or following) text, the word "noise" could be used to replace "sound" as long as the definition just given is applicable.

How Sound (or Noise) is Generated

Sound or noise can be generated in three ways. The most common of these is the vibrations of solid structures such as machines or wall panels which alternately compress and rarefy the air in contact with these structures. See figure 15. The rate or frequency at which these structures vibrate determines the frequency of the sound which is radiated. Thus, a 100 Hz (6000 cpm) vibration will generate a 100 Hz (6000 cpm) sound wave.

Sounds can also be generated by the movement of air over solid structures. A typical example is shown in figure 16. Even though the structure

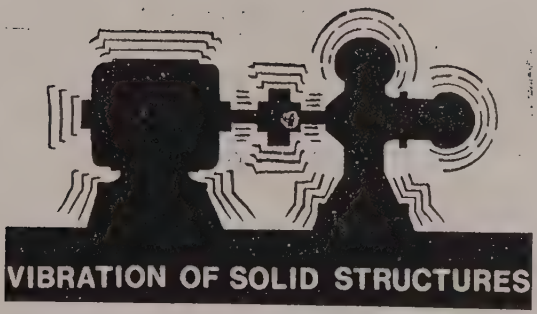


Figure 15. Most Common Source of Noise

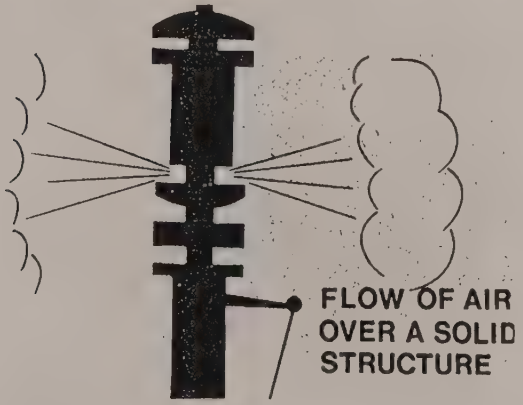


Figure 16. Air Moving Over Solid Structure Generates Noise

itself does not vibrate, the moving air can still create loud sounds. The most well-known example of this is the pipe organ. The flow of air over fan blades, or through ventilation grills, are other examples.

The third mechanism of sound generation comes from the turbulent mixing of fast moving air with relatively slow moving air in which no solid structures are involved. An example of this which is commonly heard is the noise from a jet engine. See figure 17. This type of sound only becomes important when the air (or gas) is moving at very high velocity.

All three of these sound generating mechanisms are commonly found in many types of industrial machinery; and by recognizing them, it is often possible to reduce them to acceptable levels.

Figure 17. Fast-moving Air Mixed With Slow-moving Air Generates Noise

The Decibel

Sound, or noise, is measured in units called "decibels," which are abbreviated "dB." They are as easy to use as mils, microns, inches, or millimeters once you get a feel for them. The levels of a number of commonplace sources of noise are given in following paragraphs to provide this "feel."

From a technical standpoint, the decibel was selected because of the tremendous range of sound levels which the human ear can hear. Sound pressure levels of interest for engineering purposes cover a ratio of one billion to one (10^9:1). This made it very inconvenient to handle with conventional linear units such as lb./in.^{2} (psi) or microbars. The decibel provides a logarithmic scale which compresses that huge linear range of one billion to one (10^9:1) into a decibel (logarithmic) range of only 180 to one (180:1).

Although it is not necessary to the understanding and measurement of noise, for those interested, sound pressure level is defined by the following equation:

$$\text{Sound Pressure Level} = \text{SPL}$$

$$\text{SPL} = 20 \log_{10} \frac{\text{Measured Sound Pressure (microbar)}}{\text{Reference Sound Pressure (microbar)}}$$

where Reference Sound Pressure = .0002 microbar (or 20 micronewtons per square meter).

Common Noise Sources and Levels

Figure 18 shows representative decibel levels encountered by people during the course of a day from common noise sources other than industrial.

Of course, these are only given as typical levels. Each of these sources can vary over a wide range depending upon a number of factors such as changing conditions at the "typical" source, the distance one is from the source, and the presence or absence of solid flat structures or surfaces which reflect the noise.

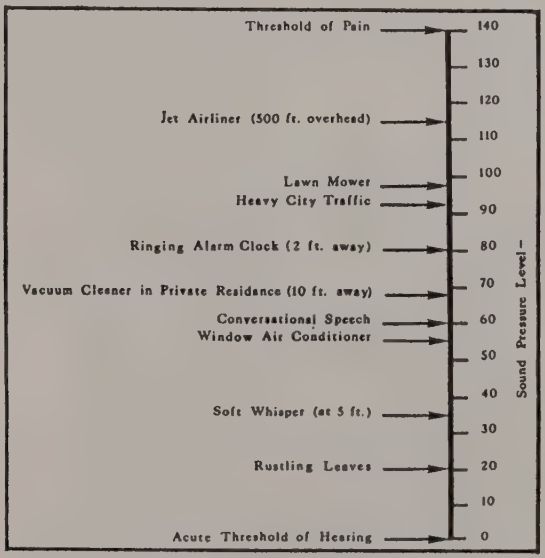


Figure 18. Common Non–Industrial Noise Levels

Industrial Noise

Noise generated by industry may be divided into two classes: those sources which affect the community around the industrial site, and those that affect the personnel on the site.

Large I. D. Fans, large transformers and high-pressure steam breakdown are examples of sources which can cause community noise problems. Diesel engines, compressors, chippers and grinders are a few of the sources which can affect personnel efficiency within a plant. Figure 19 provides examples of noise levels from industrial sources.

Acceptable Noise Levels for Different Working Areas

Numerous experimental studies have shown that workers' efficiency can be affected in varying degrees by noise. Tasks requiring a great deal of mental concentration and exactness are affected by noise to a significantly greater degree than others. For instance, even relatively moderate noises tend to dilate the pupils of the eyes, which results in a change in the eyes' focus. Thus, a watchmaker, and others who do close work, will experience difficulty in working where periodic loud noise is present.

In many cases the ability to verbally communicate is the governing criterion for acceptable noise levels. Here again, there is some variability; levels required for a conference room will differ from those required in a machine shop, or in the engine room of a ship.

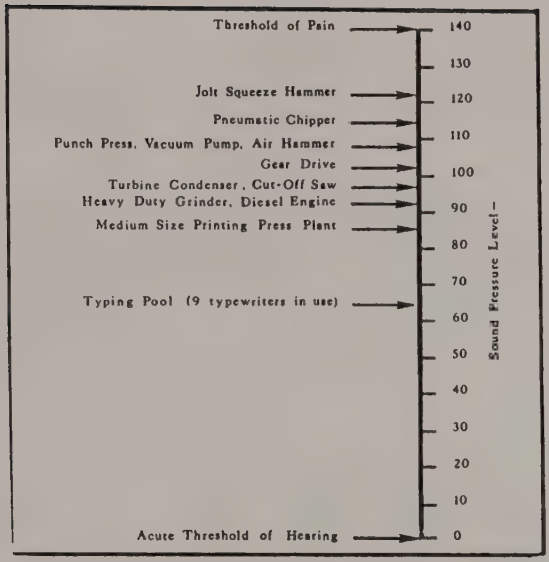


Figure 19. Typical Industrial Noise Levels

Where high noise levels occur in areas where work is less exacting and more routine, acceptability levels are governed by noise which can cause personnel fatigue and inefficiency. Figure 20 indicates some general guidelines on levels of acceptability for noise in different areas and conditions.

NOISE LEVEL dB(A)	COMMUNICATION REQUIREMENTS	TYPICAL ACTIVITY OR WORKING AREA
110	Communication nearly impossible. Maximum shouting required at a distance of one foot or less	
100	Shouting required: Communication difficult even at one foot distance	
90	Shounting required at one feet. Maximum level at which telephone can be used	
85	Raised voice can be understood at two feet	All working areas: For most tasks, worker effiency is effected above this level
70	Telephone use not a problem up to this level. Normal voice can be understood at three foot distance	Machine shop, restaurants, busy department store
65		Secretarial offices
55	Normal voice can be understood at 12 foot distance	Conference room, class room
50		Private office, drafting room, where close exacting work is required.
30		Broadcast studio

Figure 20. Guidelines for Acceptable Noise Levels

How the Ear Hears

The ear is a remarkable "sound instrument" in that it functions over an extremely wide range of amplitudes and frequencies, can detect very small changes or differences in amplitude and frequency, and with experience can even do a good job of "judging" the actual frequency (or "tone") of a specific sound.

In judging "loudness," however, the ear tends to respond poorly to sounds having frequencies near the low and high ends of a range of 20 to 10,000 Hz. This is particularly so at the lower end, i.e., from about 200 Hz down to 20 Hz. Sounds having frequencies between the range of 200 to 6000 Hz are "heard" essentially as their actual levels (or may even be amplified slightly)

Still another factor in this "poor response" characteristic of the ear is that as sound pressure level increases the response improves. For example, at 20 Hz an 80-dB SPL will be "heard" as a "20-dB sound" (a response error of 60 dB), whereas a 130-dB SPL will be heard as a 100-dB sound (an error of only 30 dB).

A, B and C Weighting Networks

Since sound is often measured in conjunction with a problem related to human hearing, it has been found desirable in many cases to use instrumentation which measures sound in a manner similar to the human ear. To do this, sound level meters such as the Model 308 are electronically designed to "hear" poorly at low and high frequencies, and "hear" best around 4,000 Hz (240,000 cpm). The response "curves" of the Model 308 to sound of different frequency, depending on the A, B or C mode selected, are shown in figure 21. The electronics which generate this type of response are correspondingly called the A, B and C "weighting networks."

As mentioned previously, the ear responds differently to sounds of different levels. Thus, for low-level sounds (below 55 dB), the A weighting

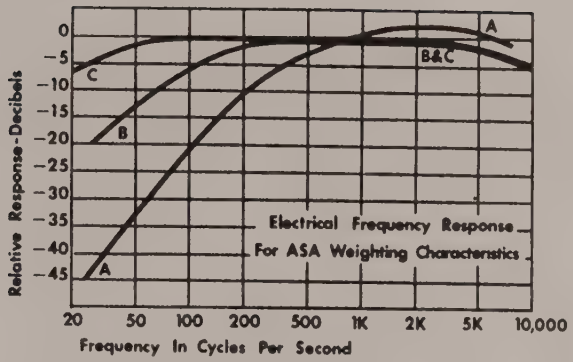


Figure 21. A, B and C Weighting Networks Response Curves

best approximates the human ear; from 55 to 85 dB the C weighting. For data recording it is necessary to specify what weighting is being used. For example, the sound levels are recorded: 50 dB(A), or 75 dB(B), or 92 dB(C), etc.

In many cases, to simplify the measurement and recording of the measured sound, standards have been set which call for measurement using a specific weighting network regardless of the level of the sound. Perhaps the most prominent example of this is the Walsh-Healey Public Contacts Act, which states that sound shall be measured in dB(A) sound level.

SOUND LEVEL MEASUREMENTS

Relative Positions of the Meter and Operator

The meter should be held in an approximately level attitude, keeping the microphone pointed directly away from the body. It may be held with the carrying strap (with the hands free for recording data)

as shown in figure 3 (in Description section), or it may be hand held directly in front of the body and extended somewhat. Initially, the operator should stand so that the microphone axis will be pointing 90° from an imaginary line between the meter and apparent source. (Again, see figure 3.) Without moving forward or back, the operator can then pivot slightly left and right to note any possible change in the meter reading, taking the highest value at that position.

Initially the operator cannot readily assume from which direction the sound is arriving. (It may be from the "obvious" source, from a reflecting surface, or both.) Because of this the operator should always keep the meter squarely in front of him, and should keep his hands (or data-sheet clipboard) well clear of the microphone. Not to do so might interrupt the sound path or reflect the sound, in either case affecting the reading.

The height of the meter above the floor must also be considered. Using the carrying strap will maintain a constant height when taking a series of readings. However, this may not be the proper height; measurement requirements may call for some other height, or it may be found that a significantly higher noise level is read if the meter is raised a foot or so from waist level. Usually the important consideration is finding the height where the maximum reading is obtained, with the microphone pointed away from the body and the source to the left or right.

Measuring Machinery Noise

The positions selected for measurement of machinery

noise depend upon the purpose of the measurement. For example, some government regulations require measurements at positions which will be representative of locations of workers' ears, since their purpose is to control the amount of noise to which workers are exposed. Other standards require measurement at a number of fixed positions (e.g. 3 ft. from machine surface, on each side of machine at the height of its centerline, and at the mid-length of the machine). Such measurements are generally made by machinery manufacturers to permit estimation of the noise a machine will make when placed in different surroundings. Still other standards require measurement positions at which the sound pressure level is the highest in order to estimate whether the machine will be a community noise problem.

From the standpoint of the measurement of industrial noise, where the objective is compliance with the government regulations and other similar hearing conservation standards, a good approach is as follows:

1. Sketch an overhead or "top" view of the machinery configuration to be measured, on a form such as the Mechanalysis PMP Data Sheet (Form No. 278A). (This same form is used for periodic vibration checks.) See figure 22. Note that the region around the machine is divided into four quadrants (1,2,3,4) at the coupling between the driver and driven unit. One sound measurement is to be made in each quadrant.

2. The machine is checked to determine that it is operating at its standard condition (temperature pressure, flow, load, speed, etc.) and these condi-

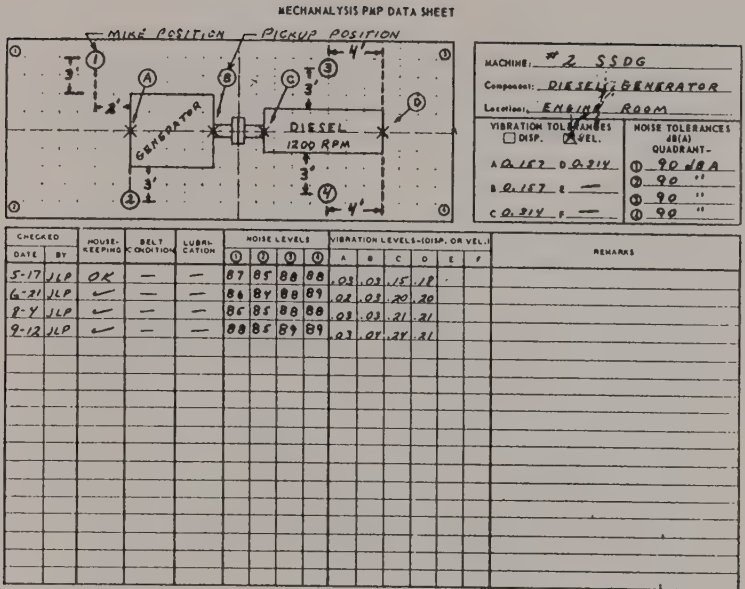


Figure 22. PMP Data Sheet Used for Vibration and Noise

tions noted on the PMP data sheet.

3. The microphone is installed in the Model 308 MICROPHONE receptacle and the desired A, B or C mode selected. (Refer to "Selecting A, B and C Networks" in following text for details.)

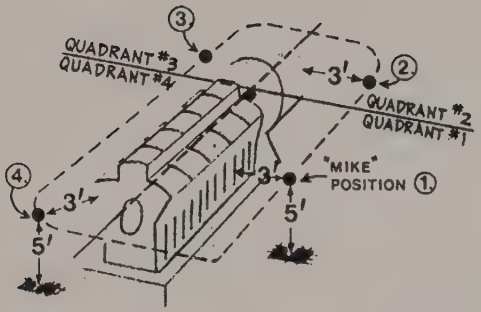
4. The microphone (i.e., the meter/microphone combination) is positioned in quadrant 1 by locating it 5 ft. above the floor and 3 ft. from the machine surface. The microphone is then moved slowly along the machine at this 5-ft. height and 3-ft. distance until the position of highest sound level in the quadrant is determined.

5. The microphone is moved around within an approximate one cubic foot volume at this position, and the variation in sound level noted. If this variation is 3 dB or less, then this position is satisfactory. If variations are greater than 3 dB, the microphone should be moved (for example) to a distance of 5 ft. from the machine, and the position of highest sound level re-established.

6. A check must also be made to make sure that the microphone is more than 3 ft. from reflecting surfaces. Large flat structures such as walls cause the greatest reflections, but other surfaces such as large adjacent machines can also cause reflections. When the noise level increases as the microphone moves away from the noise source and toward a wall, this is a sign that the measurement should be made nearer the machine.

7. Once the measurement position has been established, it should be permanently located by a suitable mark on the floor, and by dimensioning the position on the PMP Data Sheet. See figure 23.

8. If, in addition to the above, there are operator stations near the machine, sound measurements should also be taken at these locations. The microphone should be located at the approximate position of the operator's ear. The machine



TYPICAL METHOD FOR ESTABLISHING MICROPHONE POSITIONS

Figure 23.

Establish Microphone Positions With Floor Marks and Data Sheet Diagram

operator should not be near the microphone when the measurement is taken. Such data should be appropriately identified on the data sheet and in the sketch.

Selecting A, B and C Networks

The selection of which network to use is generally governed by the standard under which the noise measurements are being made. For instance, the Walsh-Healey Act specifies that the "A" network will be used. If the degree to which communication is hindered by noise is of primary interest, again the "A" is used because it has been found to be a good measure of speech interference.

On the other hand, if the noise measurement is being made to track down an unknown (but annoying) source of machinery noise the "C" network is the better choice, since it does not discriminate against low frequencies.

Although the "B" network has not been used to a great extent in industrial applications, there may be cases where it is useful.

Measuring Background Noise

Sound measurements of a given machine are more frequently subject to interference from other sources than are vibration measurements. For this reason, it is desirable to make initial measurements both with and without the machine running. By comparing the levels under these two conditions, it is possible to determine the extent of the noise contribution from other sources when measuring the machine's noise. If the level with the machine running is 10 dB above the background level, there is essentially no interference from the other sources. At the other extreme, when the noise level doesn't change when the machine is turned on, then the other sources dominate. In this case, a valid measurement of the machine's noise can only be obtained if the other sources are shut down.

Then the Noise Level Oscillates with Time

It is not uncommon to find that the measured noise level oscillates in amplitude. This can be caused by several conditions: 1) the source itself can be unsteady, 2) two sources with slightly different frequencies can be beating together, or 3) the path by which the noise reaches the microphone can be

varying. If the oscillation cannot be eliminated, the maximum and minimum measured levels are recorded.

To obtain a more accurate evaluation of changing or oscillating levels, the FAST response push-button on the meter may be used. Check the reading using both fast and slow response to see if there is any significant difference before deciding that fast response is necessary. Data taken in the FAST mode should be noted as such when recorded.

Measuring Impact Noise

Many noises in industry are not steady. These are the "clangs," "bangs" and "thuds" of forges, steam hammers and presses, rather than the steady "roar" and "rumble" of turbines, fans and compressors. Since impact noise affects human hearing differently from steady-state noise, it is important to be able to distinguish between the two. An "impact" is a single collision of one mass in motion with a second mass which may be either in motion or at rest. The Walsh-Healey Act defines impact noise as those sounds which have peak amplitudes at intervals greater than one second. Specifically, it states:

"If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous."

The Act further states that:

"Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level."

In measuring impact noise it should be noted that

the measurement must be in dB peak sound pressure level, not dB(A). "Peak" means the maximum overall amplitude of noise sound pressure. Thus, the dB(A) scale is not satisfactory, since it attenuates the amplitude of the low frequency noise.

Where many impact noise measurements are to be made, it is desirable to use a specialized instrument called an impact noise meter, or impact noise analyzer. For occasional impact noise measurements, however, reasonably good approximations can be obtained with the Model 308.

To make an approximation with the Model 308 the "C" mode or network is selected, the range selector is set at "120", and the FAST response pushbutton is held down. If the measured impact noise does not exceed 125 dB(C), then the impact is considered to be below 140 dB peak. This, however, is true only if the duration of the impact noise is greater than 5 milliseconds. If the impact duration is less than this, the actual impact level could exceed 140 dB peak. For this reason the impact noise meter is preferable.

Another method of impact noise measurement is to connect an oscilloscope to the ANALYZER output of the Model 308. Amplitude levels are scaled on the scope using a steady reference signal at various amplitudes such as 90, 100 and 110 dB. Impact noise amplitude is then noted on the scope by visual observation.

Frequency Analysis of Noise

When excessive noise is detected either because of personnel complaints, or because of routine period-

ic noise checks, the next step is to make a frequency analysis of the noise to determine its cause. To do this, the Model 308 is interconnected with a Mechanalysis Vibration Analyzer/Dynamic Balancer. (Refer to "Utilizing ANALYZER Output" in Operation section.) A typical setup is shown in figure 24. Note that the Model 308 microphone is placed so that it is perpendicular to the noise path, and the equipment is arranged so as not to interrupt the path. Also, the Model 308 is placed in a fixed position, rather than using the hands or carrying strap.

The analysis procedure (similar to that for vibration analysis) determines the major frequencies contributing to the overall noise. The frequencies detected will usually be equal to the machine rotating speed (i.e., 1 x RPM) and to whole multiples such as 2 x RPM or 3 x RPM, etc. If for example a 6-bladed fan were being analyzed, a predominant noise frequency of 6 x RPM would probably be detected. The primary goal, of course, is to be able to relate the major noise frequencies to specific machine components, thus pinpointing the primary source (or sources) of the noise. As stated in the Operation section, the C network should be used during all noise analyses, to avoid attenuation of lower frequencies.

After (or while) determining the major frequencies, the Analyzer/Balancer strob light can be a powerful tool in helping to pinpoint their mechanical source. The strob light flash frequency is tuned to the major frequencies detected. When the light is directed on various parts of the machine, the noisy part will appear "frozen."

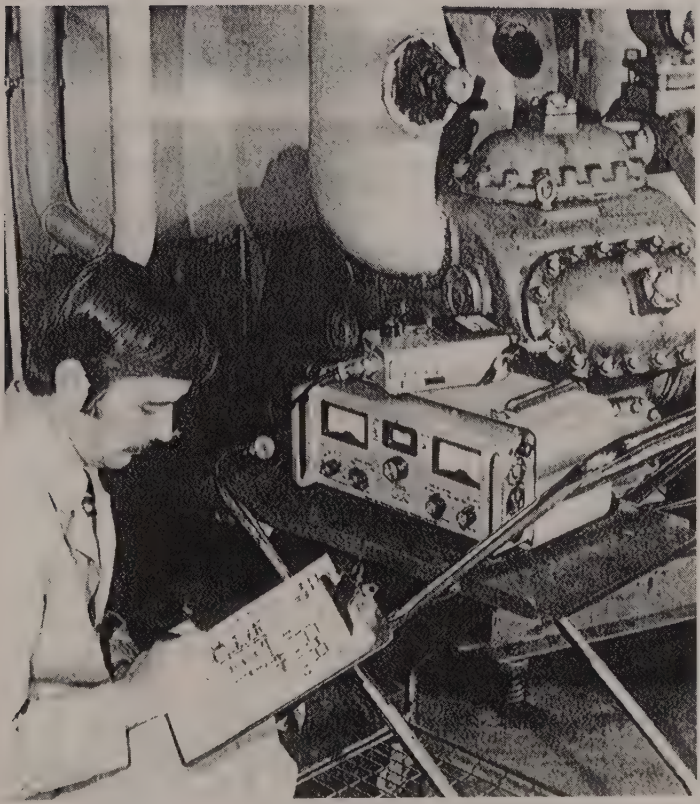
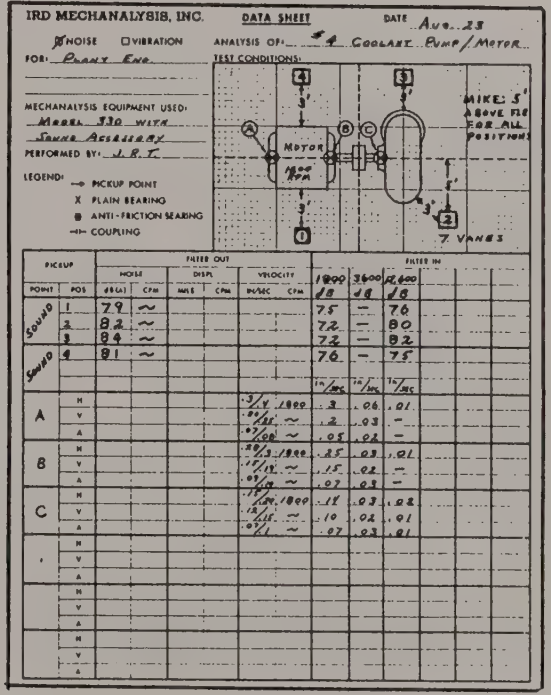


Figure 24. Typical Setup for Noise Analysis

The noise analysis can be performed independently, or in conjunction with a vibration analysis. The form shown in figure 25 is designed specifically for analysis data, and provides space for recording both noise and vibration amplitudes and frequencies.



IRD MECHANALYSIS, INC. DATA SHEET DATE Aug. 23

☒ NOISE ☐ VIBRATION ANALYSIS OF: #4 Coolant Pump/Motor

FOR: Plant Eng. TEST CONDITIONS:

MECHANALYSIS EQUIPMENT USED: Model 330 with Sound Accessory

PERFORMED BY: J.R.T.

LEGEND: → PICKUP POINT; X PLAIN BEARING; ● ANTI-FRICTION BEARING; ⊣⊢ COUPLING

MOTOR 1800 RPM

MIKE: 5' ABOVE FLR FOR ALL POSITIONS

7 VANES

PICKUP		FILTER OUT						FILTER IN					
		NOISE		DISPL.		VELOCITY		1800	3600	12,600			
POINT	POS	db(A)	CPM	MILS	CPM	IN/SEC	CPM	dB	dB	dB			
SOUND	1	79	~					75	—	76			
	2	82	~					72	—	80			
	3	84	~					72	—	82			
SOUND	4	81	~					76	—	75			
								IN/SEC	IN/SEC	IN/SEC			
A	H					.3/4 1800		.3	.06	.01			
	V					.04/1 ~		.2	.03	—			
	A					.07/2 ~		.05	.02	—			
B	H					.20/3 1800		.25	.03	.01			
	V					.17/4 ~		.15	.02	—			
	A					.09/5 ~		.07	.03	—			
C	H					.1/4 1800		.18	.03	.02			
	V					.12/5 ~		.10	.02	.01			
	A					.07/1 ~		.07	.03	.01			
	H												
	V												
	A												
	H												
	V												
	A												
	H												
	V												
	A												

Figure 25. Typical Noise and Vibration Analysis Data Sheet

After analyzing and correcting the problems which exist, additional readings should be taken using the analysis setup, and the noise reduction obtained noted on the analysis data sheet. Overall reduction (as read on the Model 308) may be entered on the form used for periodic noise measurements. Retaining this data may be useful as documented evidence of an on-going Noise Control Program.

NOISE MEASUREMENT APPLICATIONS

Preventive Maintenance

Noise measurement and control is a logical extension of the machinery vibration preventive maintenance program because of the close relationship of noise to machinery mechanical condition. In the preceding sections, it was shown that the instruments, procedures, data records and personnel involved in the vibration preventive maintenance program can be utilized equally effectively for noise measurement and control. In fact, noise and vibration measurements, incorporated in a single preventive maintenance program, can provide mutual back-up data when made simultaneously. For example, when high vibration levels are detected and machine defects are subsequently corrected, noise measurements taken before and after correction can provide evidence of an effective noise control program. Alternately, an increase in noise levels may signal a vibration problem which was not detected by vibration measurements. Severe cavitation in a valve at a location removed from a machine is an example of such a problem. Thus, by combining the noise measurements with the vibration Preventive Maintenance Program, the program is strengthened, noise control established, and the man hours required to

work an effective program are minimized.

Integrating noise measurement in the vibration Preventive Maintenance Program is accomplished by following the same basic techniques used for the vibration program, and applying the appropriate measurement techniques given in this section.

Quality Control

The noise levels of new operating or production machinery, or purchased product components, can be checked against the manufacturer's specifications, or the specifications stipulated with the purchase order. Noise tests of finished products or assemblies will ensure compliance with internal quality control standards, or those specified by customers.

Field Service

The Model 308 provides the field engineer or serviceman with a three-fold approach for verifying whether or not customer complaints are justified. Both vibration and noise levels may be determined and related to alleged machine problems. Finally, noise data may be taken in the machine or installation area to demonstrate compliance with personnel exposure standards and safety requirements, community noise pollution restrictions, etc.

Personnel and Community Problems

Excessive plant noise, regardless of the source, creates a wide variety of administrative problems. These problems are highlighted in subsequent paragraphs. Initially, management must be aware of the problems that can exist due to excessive noise.

Assuming this awareness, sufficient data can in most cases be obtained with the Model 308 to determine whether or not the types of problems described exist, and if so to what extent. Correction of those problems that do exist will require one or more of the following courses of action, depending on their severity:

1. Quiet the source. The source will almost always be mechanical equipment. Correcting existing mechanical problems provides the dual benefit of lowered noise level and extended machine life. Beyond this, controls such as mufflers and acoustical enclosures or coverings, etc., may be considered, with machine redesign as a final alternative.

2. Isolate personnel from the source.

3. Limit exposure time of personnel.

4. Provide ear muffs or ear plugs to individuals in affected areas.

Personnel Efficiency

When noise levels in industrial areas are high, it becomes difficult to communicate. Orders must be given in as brief terms as possible, and discussion of problems is only barely possible. Further, the chance of misinterpretation of verbal information increases, and beyond a certain noise level, communication becomes impossible. In offices or precise-work areas as noise increases worker efficiency starts to decrease, since it becomes increasingly difficult for personnel to concentrate on their work.

To make an initial evaluation in a specific area, refer to the noise levels given for typical working areas, in figure 20. If measurements indicate higher levels, efficiency is most likely being affected.

Safety

The relationship of excessive noise to personnel safety can readily be appreciated. In excessive noise, unheard "safety" warnings such as a shouted "Stop!", the sound of an approaching vehicle, or the noise made by a change in a machine's condition may result in serious injury. Misinterpreted instructions may bring the same result. The key to this problem is an awareness of the various safety factors in a given area, such as amount of vehicular traffic, types of machines being controlled, and the need for accurate communication. Once the safety "problem possibilities" are identified safe noise limits to combat them may be established, and the area measured to determine if the limits are exceeded. The charts shown in figures 19 and 20 may be helpful in establishing the necessary limits. (The values in figure 20 are in dB(A), while the values in figure 19 are in SPL. To best approximate SPL values the C network should be used for comparative measurements.)

Community Noise Pollution

With increasing concern about pollution caused by industry, noise has received more than its share of attention. Community action against noise nuisances is becoming more frequent, and is receiving a more sympathetic hearing from the courts and the public. This clamp-down on noise will

continue and become more and more restrictive as new noise control laws are enacted.

To evaluate possible problems a noise survey around the immediate plant perimeter should be made, noting which areas have the highest levels, and their values.

An important factor to be considered is that the highest noise level measured at the plant will be heard at essentially the same level in the surrounding community when the noise is carried by wind. Hence, the direction of the prevailing wind and the nature (business, residential, population density, etc.) of the community area "downwind" will both relate to the severity of the problem.

Closing off or baffling the path from high-level sources to the outside may be considered if quieting the sources is impractical.

Hearing Damage

One of the major topics under the subject of Noise Control is "Hearing Damage." That this is true stems from the simple, well-proven fact that prolonged exposure to excessive noise will result in permanent hearing damage. The extent of possible damage can range from a slight reduction in hearing ability to total loss of hearing. Although the fact (and the contributing causes) have been with us throughout the Industrial Age, it is only in the recent past that enough knowledge on the problem has been obtained to deal with it effectively. As this knowledge emerged, so did regulations spelling out what must be done. Although such regulations have been initiated primarily at the

Federal level, State and Community agencies have enacted or are considering similar regulations.

The most important regulation of this type is contained in the Walsh-Healey Public Contracts Act under Section 50-204.10 (dated May 20 1969 and as revised July 15 1969). The importance of the regulation lies in (1) the definition of those manufacturers or organizations who must comply with the regulation and (2) the criteria set forth for protecting the hearing of personnel.

The subject Section of the Walsh-Healey Act states that any manufacturer who wishes to sell to the Federal Government goods valued in excess of $10,000 or services valued over $2,500 must take steps to protect his employees' hearing. The Occupational Safety and Health Act of 1970 now enforces Section 50-204.10 to apply to all organizations engaged in Interstate Commerce.

In regard to criteria set forth in the standard, the following is taken in part from the Federal Register, Vol. 34, No. 96 (dated as noted above).

> 50-204.10 Occupational Noise Exposure.
>
> (a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table I of this section when measured on the A scale of a standard sound level meter at slow response.
>
> (b) When employees are subjected to sound exceeding those listed in

Table I of this section, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of the table, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(c) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(d) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Table I
Permissible Noise Exposures[1]

Duration per day, hours	Sound level dBA, slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

[1]When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C1/T1 + C2/T2 . . . Cn/Tn exceeds unity, then the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.

The following example illustrates the use of the noise exposure equation given with Table I above:

Several Amplitude vs Time recordings of an eight-hour shift revealed that average personnel exposure levels and durations were 87 dB(A) for 5.6 hours; 97 dB(A) for 2 hours; 110 dB(A) for 18 minutes (0.3 hour); and 115 dB(A) for 6 minutes (0.1 hour). The 87-dB(A) level is disregarded because it is less than the 90 dB(A) level where exposure duration must be considered. From this data, C1 = 2 hours and the allowable exposure at 97 dB(A) is 3 hours, or T1 = 3; C2 = 0.3 hours and T2 = 0.5 hours; C3 = 0.1 hours and T3 = 0.25 hours. Then:

$$\frac{2}{3} + \frac{0.3}{0.5} + \frac{0.10}{0.25} = \frac{2}{3} + \frac{1.8}{3} + \frac{1.2}{3} = \frac{5}{3}$$

Since the result is larger than unity (or 1), one of the actions described in paragraph (b) of 50-204.10 must be taken. In this example one or more of the noise levels related to the "C" values

must be reduced so that the total equation result will be equal to or less than 1, or personnel must be removed during one or more of the excessive noise periods. If the machine producing 97 dB(A) is mechanically corrected (by methods such as balancing or re-alignment) so that its noise is reduced to 89 dB(A), only C2/T2 and C3/T3 are used in the equation, or:

$$\frac{0.3}{0.5} + \frac{0.10}{0.25} = \frac{1.8}{3} + \frac{1.2}{3} = \frac{3}{3} = 1$$

Since this result is not greater than 1, there is no restriction of the amount of time personnel can be in the area in the eight-hour shift.

Documentation

Regardless of the type of personnel- or agency-related noise problems being dealt with, records of all measurement data, actions taken, and results obtained should be carefully maintained. Such documentation can be vital in noise-related legal action against the Company. It can also be of major significance in dealing with Local, State or Federal noise control enforcement agents.

BATTERY REPLACEMENT

Remove battery compartment cover (on switch side of meter). Slide the tray containing the batteries from the tray and remove snap-on connectors. Install connectors on new pair of batteries. (Always replace batteries in pairs.) Place batteries in tray and return tray to compartment. Replace compartment cover. Select any measurement mode, depress TEST pushbutton, and confirm readout in TEST area of meter. Turn meter off.

TROUBLESHOOTING

If a problem occurs with the Model 308, it should be turned over to an experienced electronics technician for troubleshooting. The schematic (Figure 26) in this section is included as an aid to the technician in locating the trouble. Test signals for troubleshooting may be introduced as described under "Calibration."

If the trouble cannot be determined, return the meter to the factory; include the pickup cable and both transducers with the meter; exclude items such as manual, picup holders, etc. (The Model 308 carrying case provides the safest and most practical container for return shipment. Use exterior carton to protect carrying case.)

CALIBRATION - SOUND

Use the Mechanalysis Sound Level Calibrator (Model 490) to check the Model 308 A, B and C measurement modes for readout accuracy at least once each month. If desired, the accuracy test may be made on a daily or per-usage basis, and particularly before making an important series of measurements for comparison with Local, State or Federal noise control "Standards." Proceed as follows:

Model 490 Sound Level Calibrator are listed in the following table (the Sound Calibration procedure is shown on Page 84):

CALIBRATOR ACOUSTIC OUTPUT SPECIFICATIONS

ITEM	SPECIFICATION
FREQUENCY	1,000 Hz, ±3%.
SOUND PRESSURE	110 dB re 20 μ newtons/meter^2.
ACCURACY	±0.5 dB (23°C, 760 mm Hz).
TEMPERATURE COEFF.	0 to 0.01 dB per °C.
ALTITUDE EFFECT	Approximately 0.1 dB decrease per 2000 feet increase in altitude from sea level to 12,000 feet elevation, or corresponding atmospheric pressure change (approximately each 12 mm Hz decrease).

If unable to correct the instrument malfunction, then the Model 308 and its accessories should be shipped to an IRD Mechanalysis Authorized Service Depot, or to the IRD factory for service. Instructions for obtaining service on the instrument are provided on Page 90 of this manual.

CALIBRATION

Calibration of the Model 308 should be checked often, approximately once each month. The sound level calibrator should be checked at least once each month. In addition, the calibration should be checked before important sound level measurements are to be obtained and compared with established local, state, or federal noise control standards. Calibration should be performed only by a qualified electronics technician.

Vibration Calibration

Test Equipment Required

1. AC Signal Generator, H-P Model 202C, or equivalent.
2. AC Millivolt Meter, H-P Model 403A, or equivalent.
3. One 100K ohm resistor, 1/8 W, 1%.
4. Small slotted screw driver.

Calibration Procedure

1. Depress the TEST pushbutton of the Model 308 to check the instrument batteries. If an indication within the TEST area is obtained on the instrument meter, then the batteries are OK. Otherwise, the batteries must be replaced before proceeding with the calibration. See instructions on Page 80 for details on replacing the Model 308 batteries.

2. Set the RANGE SELECTOR to the 1.0 inch/second or 30 mm/sec range. Then loosen the two Allen-head set screws in the selector knob, and remove the knob.

3. Remove the three holding screws from the Front Panel, then lift off the panel. Position the panel so that the AMPLITUDE METER can be easily read.

CAUTION: Take care to avoid excessive pulling of the wiring between the Front Panel and instrument chassis.

4. Temporarily, remount the selector knob on the RANGE SELECTOR, but do not change the range setting.

5. Connect the positive (+) signal lead of the Signal

Generator to Pin 2 of the Model 308 Unit Pickup Receptacle, and connect the negative (-) signal lead to Pin 1 of this receptacle. In addition, connect corresponding signal leads of the AC Millivolt Meter to the Signal Generator.

6. Setup the Signal Generator for an output voltage of 240 millivolts, rms on 308 units (284 mv, rms, for 308M units), and frequency of 100 Hz.

7. Depress the DISP pushbutton of the 308 unit.

8. Set the RANGE SELECTOR to 1.0 mil (30 micro meters for 308M unit), then adjust the DISP CAL control (P3) for full-scale AMPLITUDE METER deflection. Read the 0 to 1.0 mil scale on Model 308 units (30 micro-meter scale on 308M units).

NOTE: The component locations of the Model 308 or 308M instruments are shown in Figure 26.

9. Set the RANGE SELECTOR to the 0.3 inch/second range (10 mm/second range for Model 308M), and depress the VEL pushbutton. Then adjust the VEL CAL control P1 (Figure 26) so that a full scale indication is obtained on the AMPLITUDE METER. For this adjustment, use 0 to 1 scale on 308 units (0 to 3 scale on 308M units).

10. Connect the 100K test resistor between Pin A and Pin B of the Analyzer Receptacle. In addition, connect the positive (+) lead of the millivolt test meter to Pin B of the Analyzer Receptacle, and connect the negative (-) lead of the meter to Pin A of this receptacle.

11. Adjust the ANALYZER OUTPUT control (P4) so that an indication of 764 mv, rms, is obtained on the millivolt test meter for 308 units (286 mv, rms, for 308M units).

12. With glyptical or other shaft sealer, seal the adjustable shafts of controls P1, P3, and P4 to insure that the calibrated settings of these controls are retained. (Do not seal the SOUND CALIBRATION control, P2.)

13. Depress the OFF pushbutton of Model 308, turn off the test instruments, and disconnect these from the Model 308.

14. Reassemble the Model 308 Front Panel and RANGE SELECTOR to the original configuration.

Sound Calibration

Test Equipment Required

1. Sound Level Calibrator, Model 490, IRD Part No. 10922 (optional accessory).
2. Microphone, Part No. 5294 (standard accessory).

Calibration Procedure

1. Set the ON-OFF switch of the Sound Level Calibrator to ON and check that an audible (1000 Hz) tone is obtained.

2. Check that the battery indicator of the Sound Level Calibrator indicates the GREEN area. If the indication is within this area the internal batteries of the calibrator are OK; otherwise the batteries must be replaced before proceeding with the calibration.

To replace the Calibrator batteries, remove the metal plate from the bottom side of this unit. The batteries are accessible through the bottom side. Two 8.4 volt batteries are required (Part No. 9291). Make certain that both batteries are replaced. Then replace the bottom cover, and check that the battery

indicator reads within the green area.

3. Slowly insert the microphone into the Sound Level Calibrator until it is flush with the lower rim of this unit.

AUTION: Avoid rapid insertion or withdrawal of the microphone as this could cause damage to either the microphone or calibrator.

4. Set the Sound Level Calibrator ON-OFF selector to ON, and depress the "C" dB pushbutton of the 308/308M units.

5. Set the RANGE SELECTOR to the 100 dB position.

6. Adjust the SOUND LEVEL CALIBRATION control (P2) so that full-scale deflection is obtained on the dB scale (top scale) of the AMPLITUDE METER.

OTE: The P2 control shaft is accessible through the hole in the left-hand side of the instrument when the hole plug is removed. The control shaft can be adjusted with a small screw driver.

7. Depress the "A" dB pushbutton of the 308/308M units, and check that the meter indicates within °2 dB of the full-scale value.

8. Depress the "B" dB pushbutton of the 308/308M units, and check that the instrument meter indication is within °2 dB of the full scale value.

9. Depress the OFF pushbutton of the 308/308M units, and set the Sound Level Calibrator ON-OFF switch to OFF. Then disconnect the calibrator from the microphone.

10. Replace the hole plug in the left-hand side of the instrument.

NOTE: The Model 308 or 308M Vibration Sound Level Meter can be calibrated for velocity measurement in peak or rms units. The standard meters are calibrated for peak velocity indication. For instructions on calibration for rms velocity indication, contact your nearest IRD Mechanalysis Authorized Service Depot, or the IRD Mechanalysis Home Office.

PARTS LIST

MAJOR ASSEMBLIES AND ACCESSORIES	PART NO.
Model 308 Vibration/Sound Level Meter	0068
Case, Carrying	9375
Instrument Assembly	9285
Microphone	5294
Vibration Pickup, Model 544	4526
Probe, Straight	1103
Cable Assembly, 4 foot	12433
Strap, Leather	3829
Cap, ANALYZER Connector	9311
Plug, RECORDER Connector	9361
Operation and Maintenance Manual	9765

CIRCUIT COMPONENTS

Letters in Circuit Symbols in the components list have the following definitions:

B - Battery	M - Meter
C - Capacitor	P - Potentiometer
D - Diode	Q - Transistor
IC - Integrated Circuit	R - Resistor
J - Connector	S - Switch

CIRCUIT SYMBOL	DESCRIPTION	PART NO.
B1, B2	8.4V Mallory TR146X	9291
C1	6.8 uF 20 V	5396
C2	100 uF 12V	3605
C3	6.8 uF 20V	5396
C4	0.1 uF 80V	9342

CIRCUIT SYMBOL	DESCRIPTION	PART NO.
C5, C6	0.01 uF 16V	9284
C7	25 uF 12V N.P.	5464
C8	0.033 uF 5% 80V	9336
C9, C10	0.01 uF 16V	9284
C11	4300 pF 5% 500V	9279
C12	.001 uF 5% 80V	9632
C13	0.012 uF 5% 80V	9334
C14	0.0033 uF 5% 80V	9335
C15	0.0068 uF 5% 80V	9300
C16	0.1 uF 5% 80V	9342
C17	5 uF 6V N.P.	3490
C18	0.01 uF 16V	9284
C19	5 uF 6V N.P.	3490
C20	0.01 uF 16V	9284
C21	25 uF 12V N.P.	5464
C22	5 uF 6V N.P.	3490
C23, C24	0.01 uF 16V	9284
C25	15 uF 10V	9643
C26	220 uF 10V	9627
C27	100 uF 12V	3605
C28, C29	.01 uF 16V	9284
D1, D2	1N914	5398
IC1	uA776, Low Noise	9571
IC2, IC3, IC4, IC5	uA776	9269
J1	MICROPHONE/PICKUP Input	9235
J2	ANALYZER Output	8731
J3, J4	Battery Snap-on, Polarized	9264
J5	RECORDER Output	9360
M1	200 uA Amplitude	9259
P1	10 K-ohm	9631
P2	200 K-ohm	9630
P3	10 K-ohm	9631

CIRCUIT SYMBOL	DESCRIPTION	PART NO.
P4	200 K-ohm Type 62P	5125
Q1	2N5949	10466
R1	10 M-ohm 5% 1/4W	7877
R2	12.7 K-ohm 1% 1/8W	8265
R3	20 K-ohm 1% 1/8W	9274
R4	1 K-ohm 1% 1/8W	7848
R5	68.1 K-ohm 1% 1/8W	7867
R6	21.5 K-ohm 1% 1/8W	7862
R7	6.81 K-ohm 1% 1/8W	7857
R8	2.15 K-ohm 1% 1/8W	7851
R9	681 Ohm 1% 1/8W	7846
R10	215 Ohm 1% 1/8W	7844
R11	68.1 Ohm 1% 1/8W	7842
R12	21.5 Ohm 1% 1/8W	9270
R13	10 Ohm 1% 1/8W	7840
R14	100 K-ohm 1% 1/8W	7868
R15	2.2 M-ohm 1% 1/8W	9298
R16	221 K-ohm 1% 1/8W	9282
R17	1 M-ohm 1% 1/8W	9267
R18	10 K-ohm 1% 1/8W	7859
R19	1 M-ohm 1% 1/8W	9267
R20	2.2 M-ohm 1% 1/8W	9298
R21	1 M-ohm 1% 1/8W	9267
R22	54.9 K-ohm 1% 1/8W	9272
R23	78.7 K-ohm 1% 1/8W	7687
R24	18.2 K-ohm 1% 1/8W	7861
R25	54.9 K-ohm 1% 1/8W	9272
R26	36.5 K-ohm 1% 1/8W	9275
R 27, R 28	40.2 K-ohm 1% 1/8W	8675
R30	1 M-ohm 1% 1/8W	9267
R31	147 K-ohm 1% 1/8W	8548
R32	402 K-ohm 1% 1/4W	7241
R33	20 K-ohm 1% 1/8W	9274

CIRCUIT SYMBOL	DESCRIPTION	PART NO.
R34	Not used	----
R35, R36	32.4 K-ohm 1% 1/8 W	9273
R37	1 Meg-ohm 1% 1/8 W	9267
R38	825 ohm 1% 1/8 W	9645
R39	4.12 K-ohm 1% 1/8 W	7855
R40	1 K-ohm 1% 1/8 W	7848
R41	110 K-ohm 1% 1/8 W	9368
R43, 44	36.5 K-ohm 1% 1/8 W	9275
R45	536 K-ohm 1% 1/8 W	9266
S1	Range Selector	9258
S2, S7, S9	Mode Selector Assembly *	9260
S8	Fast Response	9237

ORDERING REPLACEMENT PARTS

To order replacement parts, contact your local IRD Service Depot, or the IRD Mechanalysis home office, see addresses on Page 91. On your Purchase Order, list the following information for each part:

1. Complete Model and Serial No. of instrument.
2. IRD Mechanalysis Part No. (see table).
3. Name of part (resistor, capacitor, etc.).
4. Reference symbol (R1, C1, etc.).

To order an unlisted part, supply a complete description of the part, plus its function and location.

OBTAINING SERVICE

Before returning the Model 308 for repair, contact your local IRD Service Depot or the IRD Mechanalysis home office for service and shipping instructions. Package the 308 and all accessories (pickup, cables, etc.) in a strong carton, and pad each article. Also include informtion as to the nature of the problem, and service desired.

AUTHORIZED SERVICE DEPOTS

Mechanalysis - USA
50 Huntley Road
umbus, OH 43229-1074
one 614/885-7668
614/885-7668
ex 245318
afax UF-640

Mechanalysis, Ltd.
7 Barton Street East
ney Creek, Ontario L8G 4S1
one 416/643-4284
ex 0618524
416/643-1143

Mechanalysis (UK) Ltd.
CHESTER UK
mpers Lane
aland Industrial Estate
ester, UK CH1 4LT
one 44/244/374914
ex 617034
44/244/379870

IRD Mechanalysis France S.a.r.l.
Z.A. DE COURTABOEUF
MINIPARC - BAT. 5
6, Avenue des Andes
91952 Les Ulis Cedex
Phone (16.1) 69.86.11.88
Telex 603967
Fax (16.1) 69.86.10.90

IRD Mechanalysis, (Belgium) N.V.
Excelsiorlaan, 39 Box 2
1930 Zaventem (Zoning Keiberg)
Phone (2) 721.28.33
Telex 61256
Fax (2) 725.00.17

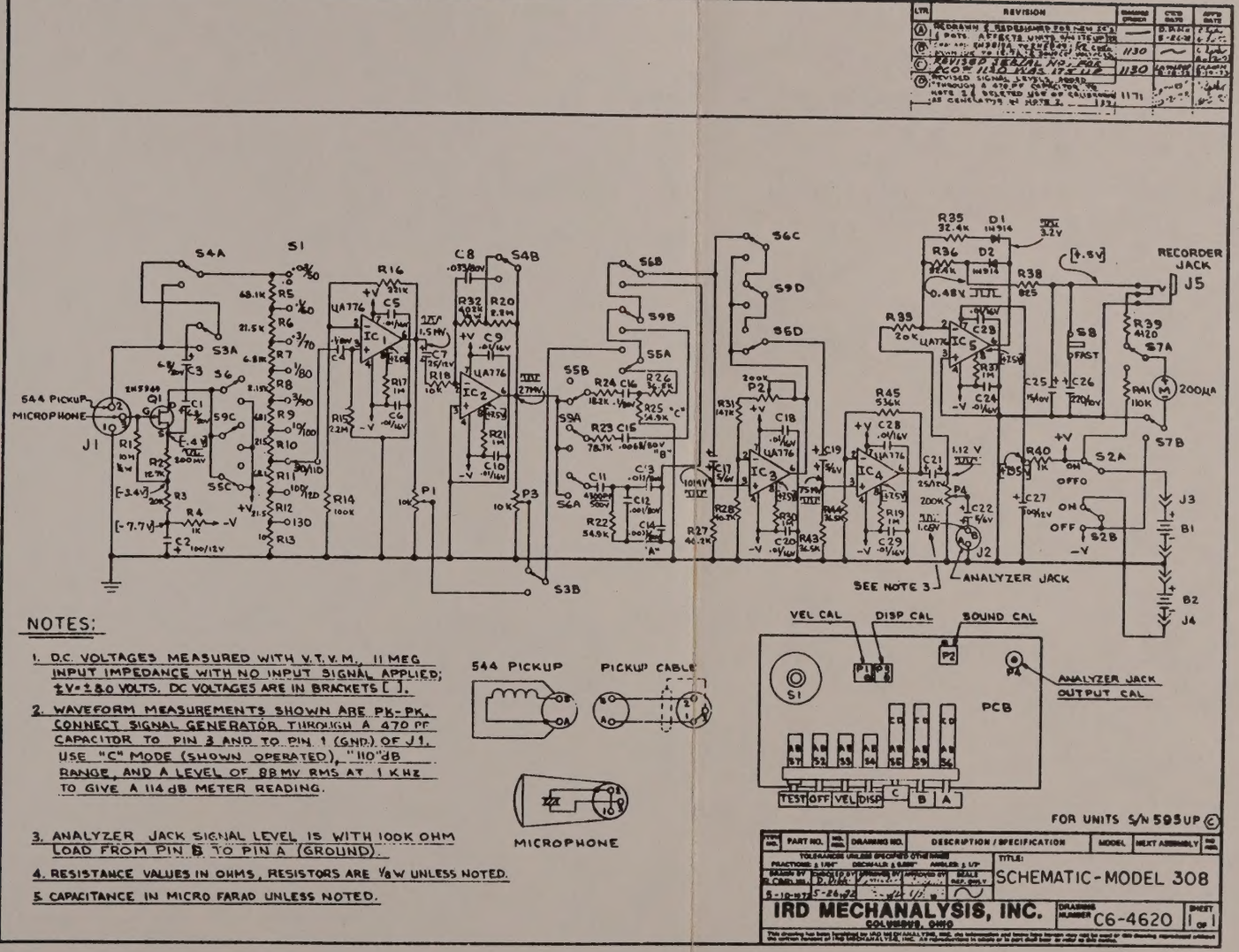
Mechanalysis, (Aust.) Pty, Ltd.
7 Pacific Highway
ows Nest, N.S.W. 2065
STRALIA.
one (02) 929 8122
ex AA 75374
(02) 922 3937

IRD Mechanalysis, (India) Ltd.
B10, Ansa Industrial Estate
Saki Vihar Road
Saki Naka
Bombay 400 072
Phone (22) 582906/589178
Telex 113209
Fax 0091222027576

MANUAL CHANGE RECORD

The following table contains a brief summary of all PCO change order, and other, changes included in the manual. The higher change letter listed in the table is also listed on the face page of the manual along with the PCO reference number and serial number of the first Model 308 instrument into which the PCO change is included.

CH. REF.	SUMMARY OF CHANGE	CH. DATE	PCO NO.
---	Changes before 3/76 not included in table.	-----	----
B	On Pages 15 and 87, Pickup Cable changed from P/N 9288, to P/N 12433, 4-foot Pickup Cable.	3-76	1609
C	Corrected cable error listing on Pages 15 and 87. Added ORDERING REPLACEMENT PARTS, OBTAINING SERVICE, AUTHORIZED SERVICE DEPOTS, and MANUAL CHANGE RECORD on Pages 90, 91, and 92, and listed in Index, Page III.	8-79	none



NOTES:

1. D.C. VOLTAGES MEASURED WITH V.T.V.M., 11 MEG INPUT IMPEDANCE WITH NO INPUT SIGNAL APPLIED; ±V=±8.0 VOLTS. DC VOLTAGES ARE IN BRACKETS [ ].
2. WAVEFORM MEASUREMENTS SHOWN ARE PK-PK. CONNECT SIGNAL GENERATOR THROUGH A 470 PF CAPACITOR TO PIN 3 AND TO PIN 1 (GND.) OF J1. USE "C" MODE (SHOWN OPERATED), "110" dB RANGE, AND A LEVEL OF 88 MV RMS AT 1 KHz TO GIVE A 114 dB METER READING.
3. ANALYZER JACK SIGNAL LEVEL IS WITH 100K OHM LOAD FROM PIN B TO PIN A (GROUND).
4. RESISTANCE VALUES IN OHMS, RESISTORS ARE 1/8W UNLESS NOTED.
5. CAPACITANCE IN MICRO FARAD UNLESS NOTED.

LTR	REVISION	DRAWING NUMBER	CHK'D DATE	APP'D DATE
A	REDRAWN & REDESIGNED FOR NEW IC'S & POTS. AFFECTS UNITS S/N 175 UP		D.A.H. 8-24-72	
B	ADDED SERIAL NO. PREFIX "C" OF 1130 AND UP	1130		
C	ADDED SERIAL NO. PREFIX "D" OF 1130 AND UP	1130		
D	REVISED SIGNAL LEVELS, ADDED 1 THROUGH 4 470 PF CAPACITOR TO PIN 3 NOTE 2 & DELETED WAY OF CALIBRATING AS CONTENTS OF NOTE 2	1171		

ITEM NO.	PART NO.	NO. REQ'D	DRAWING NO.	DESCRIPTION / SPECIFICATION	MODEL	NEXT ASSEMBLY	REF. DES.

TOLERANCES UNLESS SPECIFIED OTHERWISE
FRACTIONS ± 1/64" DECIMALS ± 0.005" ANGLES ± 1/2°

DRAWN BY: R. CARLSON 5-10-72 | CHECKED BY: D. DAVIS 5-26-72 | APPROVED BY: | SCALE: REF. ONLY

TITLE: SCHEMATIC - MODEL 308

IRD MECHANALYSIS, INC. COLUMBUS, OHIO

DRAWING NUMBER C6-4620 | SHEET 1 OF 1

Figure 26 Instrument Schematic